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HG 321

OPERATING & SERVICING MANUAL

FOR

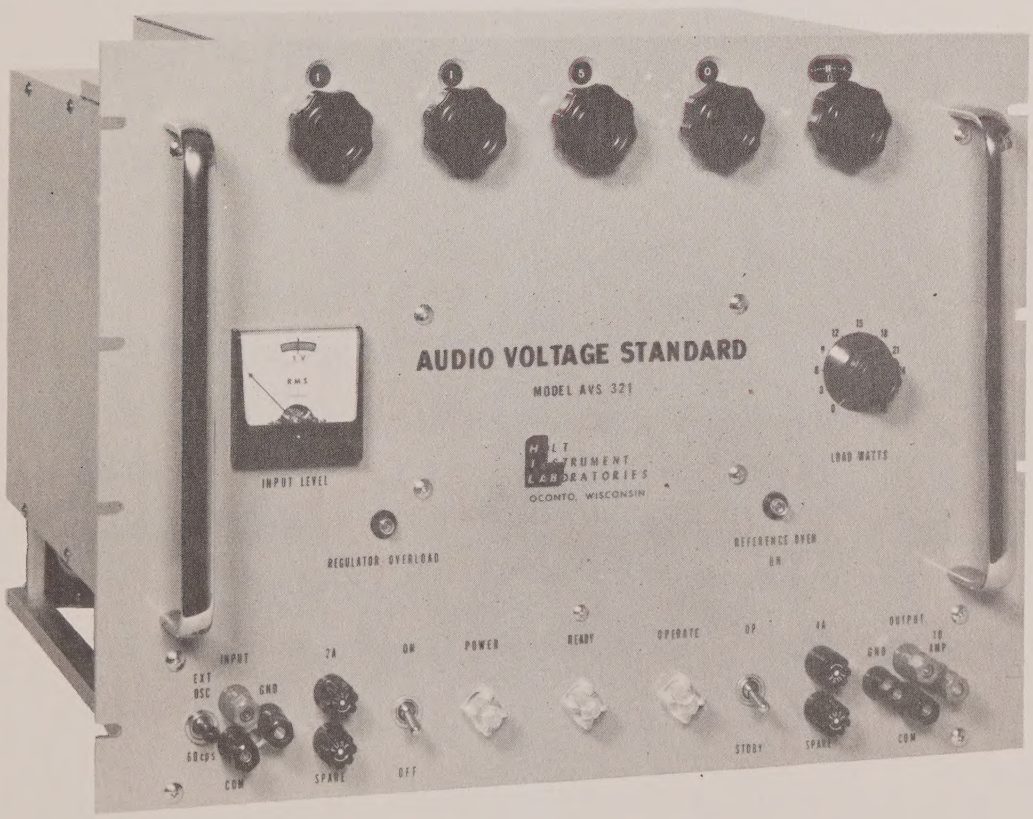
AUDIO VOLTAGE

STANDARD

MODEL AVS-321

THIS MANUAL TO ACCOMPANY

INSTRUMENT No. 1193



HOLT INSTRUMENT LABORATORIES

OCONTO, WISCONSIN

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CLAIM FOR DAMAGE SHIPMENT:

The instrument should be tested as soon as it is received. If it fails to operate properly, or it is damaged in any way, a claim should be filed with the carrier. Also, notify Holt Instrument Laboratories or the local Representative immediately. A full report of the damage should be obtained by the claim agent, and this report should be forwarded to us. We will advise you of the disposition to be made of the equipment and arrange for repair or replacement. Include model number and serial number when referring to this instrument for any reason.

WARRANTY:

Holt Instrument Laboratories warrants each instrument manufactured by them to be free from defects in material and workmanship. Our liability under this warranty is limited to servicing or adjusting any instrument returned to the factory for that purpose and to replace any defective parts thereof. Electron tubes, fuses and batteries are specifically excluded from any liability. This warranty is effective for one year after delivery to the original purchaser when the instrument is returned, transportation charges prepaid, and when upon our examination it is to our satisfaction defective. If the fault has been caused by misuse or abnormal conditions of operation, repairs will be billed at cost. In this case an estimate will be submitted before the work is started.

If any fault develops, the following steps should be taken:

1. Notify either the factory or the area Holt representative, giving full details of the difficulty, and include the model and serial numbers. Upon receipt of this information we will give you service data or shipping instructions.

2. On the receipt of shipping instructions, forward the instrument prepaid to the factory or the authorized repair station indicated in the instructions. If requested, an estimate of the charges will be made before the work begins if such work is not covered by warranty. All shipments of Holt Instrument Laboratory equipment should be packed in a strong exterior container surrounded by two or three inches of shock absorbing material.

TECHNICAL SPECIFICATIONS

REGULATION RANGE:	1 volt to 299.99 volts RMS 35cps to 10KC. 300 volts to 1000 volts RMS 35cps to 2KC.
REGULATION ACCURACY:	Regulated voltage is equal to the dial setting ± (0.1% + 2mv.) from 1 volt to 299.99 volts. From 300 volts to 1000 volts accuracy is ± 0.25%.
STABILITY:	The output will remain within the above absolute voltage tolerances for thirty days under laboratory conditions. Long-term drift may be corrected by a simple adjustment against a primary lab. standard.
OUTPUT WAVEFORM:	Sinusoidal.
DISTORTION:	0.15% 1 volt to 299.99 volts + input distortion. 0.5% 300 volts to 1000 volts. Lowest distortion will be obtained when driven from an oscillator having less than 0.1% distortion.
INTERNAL OSCILLATOR:	60 cps Harmonic distortion less than 0.1%.
REGULATION RESPONSE:	The regulator has a maximum time constant of 200 milli-sec. and a damping factor of 0.6.
OUTPUT CURRENT:	Unity power factor 10 Amps. @ 1 volt 3 Amps. @ 1.1 volt to 9.99 volts 300 Ma. @ 10 volts to 99.99 volts 100 Ma. @ 100 volts to 299.99 volts 30 Ma. @ 300 volts to 1000 volts
REQUIRED DRIVING VOLTAGE:	Approximately 1 volt RMS 35cps to 10KC.
POWER SOURCE:	105 volts to 125 volts 60 cps. 550 watts.
MECHANICAL:	19 inch rack mounting. 14 inches high. 15 inches deep.

Since the output is continuously variable in frequency as well as voltage, complete information about the response of the unit or system under test may be obtained including the effects of resonance and time constants that lie near the normal operating frequency but may not be discovered under fixed frequency testing.

Please contact Holt Laboratories or our Representative if you have any question regarding specifications, operation or applications regarding this instrument.

1-1 GENERAL DESCRIPTION:

The model AVS-321 is an extremely stable electro-mechanical audio frequency voltage regulator. It includes a high quality audio power amplifier with a special multi-tap output transformer. It should be driven by a low distortion amplitude stable audio oscillator. Together these units form a precision source of sine wave audio frequency voltage. The unit will regulate voltages from 1 volt to 1,000 volts at frequencies from 35 cycles to 10,000 cycles.

The instrument may be used as a source for calibrating other A.C. instruments. In conjunction with an accurate A.C. voltmeter it may be used for testing components such as transformers, condensers and inductors. This method of component testing is much faster than bridge testing and tests may be made over a broad range of frequencies. The instrument also may be used as a source for frequency response testing of amplifiers and audio frequency filters, making faster, more accurate readings possible.

1-2 POWER CABLE:

Supplied with the instrument is a three conductor power cord terminated in an NEMA recommended, polarized, three-prong male connector. The large rectangular pin should connect to the common side of the A.C. power line; the small rectangular pin to the hot side of the line. The chassis of the instrument is connected to the large round pin of the connector. It is important that this be connected to a ground connection which is returned to earth with a minimum of noise. Large amounts of noise or 60 cycle voltage on the instrument chassis will affect the accuracy of regulation. See

the operating instructions for procedures to test the amount of noise present in the regulating loop.

1-3 POWER LINE VOLTAGE:

The instrument is designed for operation on power line voltage of 115 volts plus or minus 10%. If line voltage is consistently high or low the power transformers are provided with taps for 105 and 125 volts. In using these taps care should be taken to prevent prolonged operation on high or low line voltages.

1-4 OPERATING TEMPERATURES:

The AVS-321 is equipped with a fan to circulate air to prevent overheating. The unit will operate without difficulty at normal ambients. However, if it is enclosed in a cabinet or rack it should be provided with enough air circulation to keep the internal temperatures below 50°C. The voltage reference zener is regulated in an oven at 55°C. Any condition that will cause the oven to lose control may alter the output voltage of the unit.

2-1 TERMINALS AND CONTROLS:

Power Switch: This toggle switch connects power to the primary of the filament transformer and to the heater of a thermal time delay relay which energizes the plate power transformer after 30 seconds. When the time delay actuates, the ready light will turn on.

Stand-by Switch: The Stand-by switch connects power to the servo motor and chopper, and connects the input to the power amplifier. The Operate light will turn on when this switch is placed in the operate position.

Fuses: The 2 amp fuse on the left side of the panel is in the primary circuit of the filament transformer. The 4 amp fuse on the right side of the panel is in the plate and servo motor supply circuits.

Decade Output Control: The five controls at the top of the panel control the output voltage by selecting the proper taps on the output transformer and the precision resistors of the regulator input attenuator.

Load Control: The load watts switch controls a resistive load on the power amplifier.

External Oscillators - 60 cycle switch: This switch connects the input of the unit to the front panel terminals or to the internal 60 cycle wien bridge oscillator.

TERMINALS:

input: The three terminals on the left side of the instrument are connected to the input of the power amplifier through the servo driven potentiometer used to regulate the A.C. Signal. The top terminal is

signal input and the bottom is signal ground. A connecting link is required between ground and common.

Output Terminals: The four terminals on the right hand side of the panel are the output voltage connections. The GND terminal is Chassis Ground. A connecting link is required between ground and common. The common and output terminals are used for all output voltages above 1,000 volts. The 10A terminal may be used for obtaining up to 10 amps of current when the output is set to 1 volt. It may also be used as a stable uncalibrated source of current for phantom load wattmeter calibration. When used this way, the wattmeter voltage terminals are connected to the output and common terminals and the current coil is connected through a Standard Ammeter and a control rheostat to the 1 volt, 10 amp terminal. The total power drawn from the voltage and current terminals should not exceed 30 watts.

2-2 OPERATION:

With unit in stand-by connect a high quality, low distortion oscillator to the AVS-321 as shown in Figure 2-2.1. Turn on the oscillator and set its output voltage to approximately 1.0 volt and the desired frequency. After allowing ample warm-up time, set the control switches to the desired output voltage. Set the load watts switch to the approximate power required by the load under test. This setting is not critical. An accuracy of plus or minus 3 watts will not affect the output voltage accuracy.

When the ready light turns on, the unit may be switched to operate. The unit should be allowed to warm-up at least 20 minutes. For maximum accuracy allow 1 hour warm-up. The output of the low distortion oscillator may vary from .75 to 1.25 volts as indicated by the green region on the input level meter. The regulator will completely correct

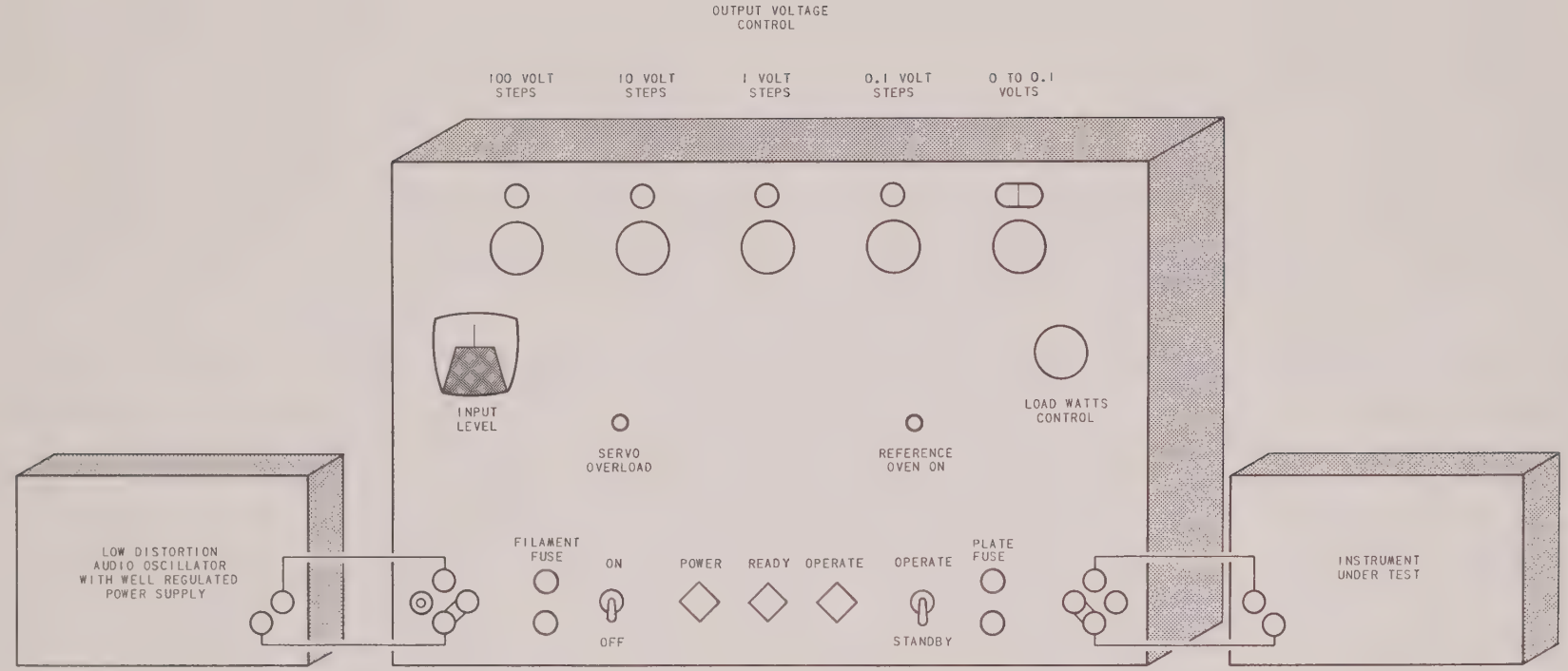

OUTPUT VOLTAGE CONTROL
100 VOLT STEPS
10 VOLT STEPS
1 VOLT STEPS
0.1 VOLT STEPS
0 TO 0.1 VOLTS
INPUT LEVEL
SERVO OVERLOAD
REFERENCE OVEN ON
LOAD WATTS CONTROL
LOW DISTORTION AUDIO OSCILLATOR WITH WELL REGULATED POWER SUPPLY
FILAMENT FUSE
ON
OFF
POWER
READY
OPERATE
OPERATE
STANDBY
PLATE FUSE
INSTRUMENT UNDER TEST

Figure 2-2.1

for variations within these limits. If the oscillator output varies too much or too fast, the regulator overload light will glow in the panel. If regulator overload light continues to glow, check for the reason. This indication usually means the output is not within specified limits.

CHANGING VOLTAGE:

To change output voltage it is generally good practice to place the AVS-321 in "Stand-by" before making the voltage change. This may prevent an accidental high voltage being applied to any connected equipment. If currents of one ampere or more are being drawn in the range below 10 volts then it is advisable to place the AVS-321 in "Stand-by" to prevent arcing of switch contacts and heavy transients in the unit.

At other times it may be advantageous to be able to adjust the output voltage with the test setup in operation. This may be accomplished without endangering the AVS-321 if the dials are rotated from step to step rapidly without stopping in between dial positions.

NOTE: The output voltage is removed from the terminals when the unit is in stand-by.

CHANGING FREQUENCY:

The output frequency may be changed by changing the oscillator frequency. No readjustment of the AVS-321 is necessary. Place the AVS-321 in Stand-by when changing oscillator range.

INPUT OSCILLATOR CHARACTERISTICS:

The AVS-321 is a power amplifier with a servo type voltage regulator in the feed back loop. Necessarily this regulator has a finite time constant and resolution. The time constant of the AVS-321 is less than 0.2 sec. The system has a damping factor of 0.6. Servo dead space is approximately 0.01%. Due to these factors small short-term

variations in the input signal will not be corrected by the regulator.

In most calibration work, where thermo-couple or moving coil instruments are being calibrated, the time constant and damping of the meter being read are long enough to filter out most of these short-term transients.

When calibrating the new expanded scale and digital instruments which have extremely high resolution and short time constants any small variation in the oscillator output will be seen as a fast fluctuation in the reading or a cyclic variation in the least significant digit of the digital meter.

If these variations are a problem we recommend the use of Holt Instrument Laboratories Model A0-400 fixed frequency 400 cycle oscillator or Model A0.1 variable frequency oscillator. These oscillators are amplitude stabilized for very low short-term jitter.

GROUNDING AND INTERFERENCE:

To test the instrument for the presence of excessive 60 cycle hum in the ground circuits connect an oscilloscope to test points TP 101 and TP 102 on the servo amplifier board. TP 101 is the grounded terminal. The peak to peak voltage at this point should not exceed 50 milli-volts when the servo is at null with the instrument in operation at a frequency of 1,000 cycles. With the scope sweep at 2 milli-seconds per Cm. and sync on the line, the waveform should be a distorted 60 cycle voltage. Forcing the servo gear to one side or the other with the finger will make this error signal increase and shift phase by plus or minus 90 degrees. A change of 300 milli-volts in the peak to peak value of this waveform from its magnitude at null is equal to a change of approximately 0.1% in the regulated A.C. at the output of the AVS-321.

The instrument is wired with the output, regulator and chassis grounds connected only by the front panel ground links. This ground connection can be made at a remote point as part of a radial ground system, but it must be a low resistance connection introducing a minimum of noise and hum as extra voltages inserted in this connection will affect calibration.

SETTING THE SERVO GAIN:

The gain of the servo amplifier will affect the servo dead space and in some cases the overall short-term stability of the unit. This adjustment is accurately set at the factory as part of the calibration procedure. However, occasionally this may demand resetting, due to tube aging.

To do so, connect an oscilloscope to TP 101 and observe the error signal, unit in Operate, starting with R-118 (Servo gain adjustment) fully counter-clockwise. The servo motor is fully disabled and the error signal will be large, dependent on the difference between the output of the AC-DC converter and the reference voltage. Adjust R-118 by turning it clockwise until the servo motor seeks a null position. The error signal at this point should reduce in amplitude to nearly a straight line. Occasionally, it may become larger as the servo attempts to stabilize the output signal amplitude. Continue to turn R-110 until a point is reached where the error signal amplitude becomes large again. At this point the servo gain is excessive and the servo gear will jitter rapidly. Turn the servo gain adjustment R-110 back until the jitter stops.

To insure that this control is properly set, place a finger against the servo gear, (below the unit on the left hand side). The gear should be stiff and require some pressure to move it off this null point. It should not be jittering. The optimum setting is

achieved when maximum stiffness is attained without allowing the servo to jitter.

3-1 GENERAL:

The AVS-321 consists of the following basic assemblies:

a. The precision VOLTAGE CONTROL permits continuous selection of output potentials from 1 to 1000 volts. It also attenuates the output voltage to the one volt AC converter input.

b. The AC TO DC CONVERTER rectifies this signal and amplifies it with a highly stable conversion gain.

c. The AUDIO FILTER filters the half wave rectified output of the Converter to a smooth DC signal having less than 0.1% peak to peak ripple.

d. The SERVO AMPLIFIER compares this DC signal to a highly stable DC reference and amplifies the difference or error to provide driving power for the servo motor.

e. The SERVO MOTOR AND POTENTIOMETER act as an automatic gain control for the input to the power amplifier, adjusting the gain of the power amplifier to maintain its output at exactly the selected level.

f. The POWER AMPLIFIER produces full output power continuously with less than 0.15% harmonic distortion. The frequency response is plus or minus one db from 35 cycles to 10,000 cycles. The output of the power amplifier is monitored and controlled by the regulator system parts (a) through (e) above.

g. The POWER SUPPLY furnishes all the AC and DC power to operate the instrument.

3-2 VOLTAGE CONTROL:

The AVS-321 provides a range of output voltages from 1 to 1,000 volts at the input frequency. The selected output is continuously

variable with the four decade switches and a variable resistor. The decade switches select the proper output transformer tap or taps to give the desired voltage. The block diagram illustrates how various taps are connected and added to achieve all possible potentials. The decade switches, in addition to selecting the proper output voltage, selects the attenuator resistor or resistors permitting a very accurate division of the output voltage to the 1 volt level fed to the AC Converter.

The attenuator is a constant current attenuator, made up of special, precision, wire wound resistors. These resistors have a very small time constant with a correspondingly good frequency response. The resistors are bridged at the time of assembly to insure accuracy of three-hundredths of a percent or better.

The attenuator is mechanically arranged for a minimum of stray capacitance both from the resistor to ground and shunt capacity across the resistors. The resistors are rigidly mounted so that capacitive effects are stable and can be compensated for at the time of calibration. Subsequently, it is very important that the physical position of the attenuator components be maintained between high frequency calibrations. Because of the lower impedances used at the lower voltages, they are somewhat less critical with respect to stray capacitance.

The output of the attenuator is 1 volt RMS into a 300 ohm load. This one volt is maintained at all of the output terminal voltages by selecting the proper attenuator resistors. This selection is done automatically by extra switch sections as the desired output voltage is selected. At one volt selected output, there are no attenuator resistors in the circuit, but rather the one volt is fed directly from the output terminals to the 300 ohm load in the AC Converter. At voltages above one volt, the proper fixed attenuation is provided.

A trim resistor is provided on the AC to DC Converter in series with the 300 ohm load to set the exact attenuator ratio. Caution is urged in that this adjustment be made only at calibration where the instrument's output can be checked against primary standards. If an accurate AC to DC transfer standard is not available this trim may be adjusted with a Wheatstone Bridge. (See calibration procedure and data sheets enclosed with each machine.)

The 10,000 ohm grid input resistor in the AC-DC Converter is shunted with a high frequency compensating network. These components provide the necessary frequency compensation. Their sizes are peculiar to each individual unit and are factory set.

3-3 THE AC TO DC CONVERTER:

The AC to DC Converter is a high gain broad band amplifier with two silicon diodes in a feedback loop which reduces the closed loop gain of the amplifier to 28 db. The diodes are arranged so that the positive half cycle of the feedback current flows through a precision resistor and the output of the converter is taken across this resistor. The output is therefore a half wave rectified voltage which is proportional to the half cycle of the feedback current. Due to the high gain of the amplifier, the summing junction at the input of the amplifier is held very close to zero potential and since there is no current flowing in the grid circuit of the input tube, the input and feedback currents are equal and the output voltage of the AC to DC converter is a function only of the input voltage and the values of the precision resistors located in the feedback loop. Referring to Figure 3-3-1 the circuit operates in accordance with the following equations.

Since the input grid draws no current

eq. 3.3.1 $I_2 = 0$ Therefore $I_1 = I_3$

eq. 3.3.2 $$\frac{E_{In} - e}{R_1} = \frac{e - E_2}{R_2}$$

THEORY OF OPERATION:

Solving 3.3.2 for E_2

eq. 3.3.3 $$E_2 = -\frac{R_2}{R_1} E_{In} + e\left(1 + \frac{R_2}{R_1}\right)$$

Let K equal amplifier gain from point A to B.

eq. 3.3.4 $$e = -\frac{E_2}{K}$$ Where the minus denotes phase inversion in the amplifier.

And since $R_1 = R_2$

eq. 3.3.5 $$E_2 = -E_{In} - \frac{2E_2}{K}$$

Or

eq. 3.3.6 $$E_2 = -E_{In}\left[\frac{1}{1 + \frac{2}{K}}\right]$$

During the positive half cycle of the amplifier output

eq. 3.3.7 $$\frac{E_2 - E_{out}}{R_4} = \frac{e - E_2}{R_2} + \frac{0 - E_2}{R_5}$$

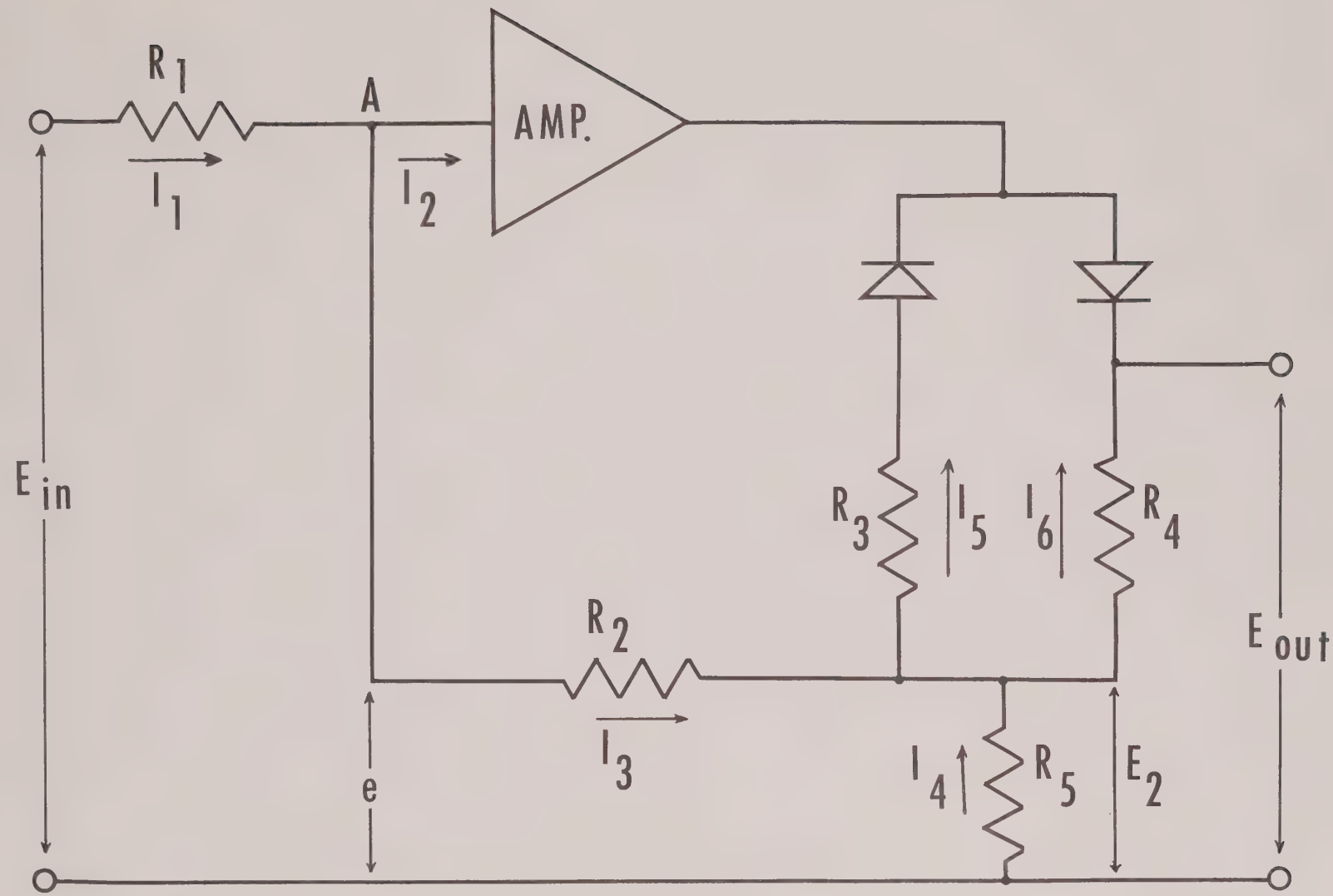
Substituting eq. 3.3.4 in eq. 3.3.7 and solving for E_{out}

eq. 3.3.8 $$E_{out} = E_2 + E_2 \frac{\frac{R_4}{R_2 R_5}}{R_2 + R_5} + \frac{E_2}{K}\frac{R_4}{R_2}$$

During the negative half cycle of the amplifier output, assuming perfect diodes:

eq. 3.3.9 $I_6 = 0$ and eq. 3.3.10 $E_{out} = E_2$

from 3.3.6 if E_{In} has no DC component E_2 has no DC component and the positive half cycle of E_2 in the first factor of eq. 3.3.8 is exactly cancelled by the negative half cycle of eq. 3.3.10



Block Diagram
A.C. to D.C. Converter
Fig. 3-3-1

In this instrument $R_4 = R_2$ and $E_2 = 1$ volt RMS

therefore the factor:

eq. 3.3.11 $$\frac{E_2}{K}\ \frac{R_4}{R_2} = \frac{1}{K}$$

and the output DC voltage equals the half wave rectified average of:

eq. 3.3.12 $$E_{out} = E_2 \frac{R_4}{\frac{R_2 R_5}{R_2 + R_5}} + \frac{1}{K}$$

substituting eq. 3.3.6 in eq. 3.3.12

eq. 3.3.13

$$E_{out} = -E_{in} \frac{R_4}{\frac{R_2 R_5}{R_2 + R_5}} \left[\frac{1}{1 + \frac{2}{K}}\right] + \frac{1}{K}$$

The ratio $\frac{R_4}{\frac{R_2 R_5}{R_2 + R_5}} = 10\frac{\pi}{2}$ which is the conversion factor from the RMS input voltage to the average of the half wave rectified voltage E_{out}. This factor causes E_{out} to equal 10 volts DC when E_{in} equals 1 volt RMS. Since K is equal to 2000 the half wave rectified value of 1/K equals 0.225 milli-volts and may be neglected.

Because 435 ohms was used for R_5, instead of 472 ohms as computed, the ratio of 3.3.13 will not come out correctly. While the actual values are not critical, it is important that their values remain constant.

THE DIODES:

The silicon diodes used have a back resistance of greater than 100 meg Ω and a forward resistance of less than 1000 Ω.

The forward resistance appears in series with the output of the amplifier thereby increasing its output impedance. Doubling diode resistance at this point will only cause a 10% reduction in K and diode forward resistance changes may be neglected.

The back resistance appears in shunt with R_4 and if it were to decrease from 100 megohms to 10 megohms it would cause a change of 0.1% in the output voltage.

AMPLIFIER GAIN:

From eq. 3.3.13 it may be seen that amplifier gain affects the AC to DC conversion ratio in two ways. It has been shown that for values of K of greater than 1000 the factor 1/K may be neglected. The factor $\frac{1}{1+\frac{2}{K}}$ is equal to 0.999 for a gain of 2000. If the amplifier gain drops to 1000 this factor decreases to 0.998 or a change of 0.1% in the AC to DC conversion ratio. It should be remembered that the absolute value of the AC to DC conversion ratio is not important. The value of this ratio is adjusted when the instrument is calibrated against the primary standard. The important factor is that this conversion ratio must remain constant for periods between routine calibration checks.

3-4 AUDIO FILTER:

The Audio Filter is a low pass LC filter designed to pass the average value of the half wave rectified signal from the AC to DC converter. The response of the filter is flat from DC to 20 cycles and is down 70 db at 30 cycles and retains this attenuation to beyond 20 KC. This permits the filter to pass the amplitude variations in the AC signal without allowing the regulator to respond to the ripple in the rectified signal. The resistive pad at the input of the filter isolates the rectifier circuit from the reactive impedance at the filter input.

3-5 DC REFERENCE AND SERVO AMPLIFIER:

The DC signal from the filter output is taken through a lead lag stabilization network Z101 compared with the precision DC reference by the 60 cycle contact modulator.

The DC reference is a silicon zener diode composed of two junctions back to back with matched temperature coefficients. This diode has a

very low voltage coefficient of temperature in the zener region and the diode is mounted in a temperature controlled oven to further reduce its voltage fluctuations. The internal dynamic resistance of the diode is about 10 ohms. This means that a change of current of 0.6 ma will produce a change of 0.1% in the zener voltage of 6 volts. The zener current is derived from the regulated 150 volt supply through a resistance of 15 K ohms. A change of 11 volts in the 150 volt supply would therefore result in a change of 0.1% in the zener reference voltage.

The contact modulator G101, is a vibrating reed which mechanically switches the grid of the first stage of the servo amplifier alternately from the reference to the filter output at 60 cycles per second. This reed is driven at a phase angle of 90 degrees from the power line. The square wave output of the modulator is amplified and in the second stage of the servo amplifier converted to a sine wave by the filter Z103, in the feedback, around the tube. The gain control at the output of the second stage provides for variations in tube gain so that the servo may always be operated with a minimum of dead space. The sine wave which is proportional to the error in the AC voltage at the AVS-321 output, is further amplified and drives the servo motor to correct the error to zero. A servo motor and potentiometer are used to obtain the signal level control because this system does not introduce any distortion in the sine wave signal. The second section of the servo potentiometer is used to supply a rate feedback signal to the servo amplifier for stabilization.

3-6 POWER AMPLIFIER:

The power amplifier section is a high feedback linear amplifier designed to deliver 30 watts to a matched load with a very minimum of distortion. It consists of a triode preamplifier followed by a

grounded grid phase inverter V-704. V-705 is a push pull amplifier stage with negative feedback on its plates from the output stage. This is followed by V-706, a push pull cathode follower driver stage. The output stage is made up of four 5881's V707, V708, V709 and V710 operating in push pull parallel. The output transformer primary is divided into matched plate and cathode windings so that the stage is DC self-balancing. The output is operated in Class AB-1 with current flowing in each half during approximately 300 degrees of the cycle. The output of the transformer is fed back to the cathode of the first stage, V703. The feedback in this loop is approximately 18 db.

The first stage plate is powered from a 105 volt supply regulated by the second half of V703. This supply has extremely low ripple and noise, the peak to peak value being less than 2 mv with zero signal on the amplifier.

3-7 POWER SUPPLY:

The power supply consists of three major sections. First, the the low plate supply is a source of 380 volts DC supplying two electronic regulators, (150 volt and 250 volt), and a 105 volt VR tube regulated reference supply. Second, a negative supply of 200 volts is the source of bias voltages in the AC Converter and Power Amplifier. Third, a high plate supply is the source of the 410 volt DC plate voltages on the power output tubes and through a dropping resistor supplies a 280 volt unregulated voltage to the servo amplifier.

The 150 volt and 250 volt electronic regulators are of the series pass type and are nearly identical in operation. The 250 volt pass tube is aided by another such tube in shunt.

In addition to these power sources, a 12 volt DC supply is provided to supply the input stages of both the AC Converter and Servo Amplifier with a DC heater voltage.

3-8 60 CYCLE INTERNAL OSCILLATOR:

Because small amounts of 60 cycle hum in the system will cause the output voltage to vary at the beat frequency when operating within a few cycles of 60 or 120 cycles, the AVS-321 incorporates an internal, low distortion, 60 cycle oscillator. It is a wien bridge oscillator, synchronized from the line frequency, phase shifted in such a manner so as to provide an in phase relationship between the output voltage and the 60 cycle system hum.

4-1 STANDARDS:

The Holt Instrument Laboratories AVS-321 Audio Voltage Standard is a working standard and should not be considered a primary standard of AC voltage. It is designed and constructed with the utmost care and should have no trouble in maintaining its rated stability for the recommended calibration period of thirty days. However, with any instrument employing vacuum tubes a gradual change in tube characteristics does cause a gradual shift in calibration as explained in the theory section of this manual.

Primary standards are those standards which may be reproduced anywhere in the world to a given degree of accuracy by using specified materials and construction. The Weston normal standard cell is the primary standard of DC voltage. To obtain a primary standard of AC voltage, a transfer instrument must be used. This is an instrument which because of its basic principle of operation, will respond identically to AC or DC voltages having equal RMS magnitudes. The two instruments most commonly used for this purpose are the dynamometer and the thermo-couple transfer voltmeter.

Holt Instrument Laboratories uses and recommends the Holt Instrument Laboratories, Model TV-1, for the calibration of the AVS-321.

4-2 CALIBRATION PROCEDURE:

The AVS-321 should be calibrated under carefully controlled laboratory conditions. Any attempt to adjust the calibration casually in the factory or test lab will almost certainly result in operation outside the accuracy specifications of the instrument.

The following equipment is recommended for the calibration of this instrument:

Audio Oscillator	Holt Instrument A0.1 or Hewlett Packard 206 A
Distortion Analyzer	Hewlett Packard 330B
Oscilloscope	Tektronix 531
Transfer Standard	Holt Instrument Model TV-1
Potentiometer	Leeds Northrup K3
Standard Cells	Eppley Model 100

Variac and line voltage meter, thermometer, galvanometer, etc.

PRELIMINARY:

Set the equipment up in a laboratory with reasonably clean line voltage. Excessive transients or radio frequency noise on the power line will make the calibration more difficult. Remove the AVS-321 from the cabinet and examine it for mechanical faults. Connect the units as shown in the first section of this manual, being sure that all grounds are properly connected. The use of a good earth ground is recommended. Connect the oscilloscope to the test points on the servo amplifier. Tp101 is the ground point, Tp102 is the servo error signal (ref. Fig. 6.8). Adjust the scope for 60 cycle sweep with line sync. The vertical gain should be set at 50 millivolts per cm.

With the equipment operating, move the servo gear with your finger. The error signal on the scope will increase as the servo is forced away from null, the phase of the error changing 180 degrees as the servo passes through null. At null, the error signal should not exceed 50 milli-volts peak to peak at output frequencies above 100 cycles. Below 100 cycles, may go to 150 milli-volts depending on hum and amplitude stability of oscillator. The presence of larger error signals of 60 cycles or oscillator frequency usually indicates a faulty ground system. Monitor this error signal throughout the testing. A change in the peak to peak voltage

of 300 milli-volts is approximately equal to a change of 0.1% in the output voltage of the AVS-321.

DISTORTION:

Check the distortion at the output of the AVS-321 at 290 volts and frequencies of 35 cycles, 1 KC and 10 KC. The total distortion due to all parts of the system (oscillator included), should be less than 0.25%. If necessary, adjust the distortion balance of the power amplifier on the 5881 chassis for minimum distortion. Also check tubes V703 through V710.

DYNAMIC RESPONSE:

Slow the sweep of the scope to its minimum. Change the oscillator output 1 db by switching the attenuator switch on the oscillator. The error signal on the scope should return to within 100 milli-volts in less than 0.4 seconds.

VOLTAGE CALIBRATION:

Set the AVS-321 for 1 volt output at 1,000 cycles. Rotate the right hand voltage dial several times, then set it at extreme clockwise position. The line voltage should be at 115 volts. Temperature 20 to 30 degrees centigrade. Allow at least one hour to warm up. Check the output carefully using the transfer volt-ammeter. If necessary, correct the voltage to 1 volt by adjustment of R104, the small DC reference trim pot inside the shield can at the top of the servo amplifier chassis. Adjust the 10 volt range using R325, the trim pot at the top of the AC to DC Converter Chassis.

FREQUENCY RESPONSE:

Check the frequency response of the 10 volt range from 35 cycles to 10 KC. Small amounts of 60 cycle hum in the system will cause the output voltage to vary at the beat frequency when operating within a few cycles of 60 or 120 cycles. The peak to peak swing of these vari-

ations should be less than 0.1%. Operation exactly on 60 cycles or 120 cycles should be error free. Some of this variation may be due to the oscillator and some is contributed by intermodulation in the power amplifier. If necessary, adjust the low frequency response from 200 cycles down by adjusting the value of C311 and R326. The high frequency response from 4 KC to 10 KC is adjusted by trimming C307 and R307. This network is found on the AC converter board in shunt with R301.

It is unlikely this setting will need adjustment in the field unless some of the components on the AC to DC converter board become defective.

The frequency response should now be flat from the low frequency end to 10 KC.

5- OVERHAUL AND FACTORY ADJUSTMENT PROCEDURE:

Prior to shipment, the AVS-321 is accurately calibrated under carefully controlled laboratory conditions. Naturally the manufacturer recommends that future calibrations be similarly conducted. Any attempt to casually adjust the calibration will most certainly result in operation outside of the accuracy specifications of the instrument.

The following equipment is recommended for the calibration procedure:

Audio Oscillator ..... Holt Instrument Labs Model AO.1
Distortion Analyzer ... Hewlett Packard Model 330B
Oscilloscope ..... Tektronix Type 531
Transfer Standard ..... Holt Instrument Lab Model TV-1
Potentiometer ..... Leeds Northrup K2 or K3
Otto Wolff KF-4 or KF-5
Standard Cells ..... Eppley Model 100
Vacuum Tube Voltmeter.. 11 meg ohm input resistance
3% full scale accuracy
Wheatstone Bridge..... Otto Wolff 944
Variac, line voltage meter, thermometer, galvanometer, etc.

VISUAL INSPECTION:

With power off, visually check for shorts, poor solder joints, loose or broken wires, missing or burnt components, etc.

MINIMIZE SERVO MOTOR AND POTENTIOMETER MECHANICAL FRICTION:

The maximum motor, gear and pot friction is 3 inch ounces on the potentiometer shaft. Should this be excessive, remove the motor gear and check the motor and pot independently. If neither seems excessive, the gear mesh itself can be adjusted by loosening the set

screw in the eccentric bearing on the pot shaft. By slowly turning the eccentric, the degree of gear mesh can be optimized to give quiet, close mesh with a minimum of friction. Reset the set screw after completing the adjustment.

SET THE .01 VOLT DECADE VARIABLE RESISTOR:

Connect a bridge or ohmmeter that draws less than 50 ma. across the variable resistor, (R-644). Set the stop so that the resistance at the clockwise extremity is zero and 30 ohms at the counter-clockwise extremity and there are no discontinuities between the extremes. Loosen the knob set screw and turn the dial to zero with the resistor set at its clockwise extremity.

BRIDGING PRECISION RESISTORS:

Ground the point between R-301 and C-304 on the AC-DC Converter subassembly. Disconnect the purple and white lead from the wiper of S-600-C in the attenuator. Connect the bridge between this point on S-600-C and ground. See Figure 5.1.1 for dial settings and corresponding resistances. All resistors should be within three hundredths of a percent of the indicated value.

To bridge the precision resistors on the AC Converter subassembly simply remove all the jumpers soldered between test points throughout the circuit. Also disconnect AC Converter from the attenuator. This procedure isolates all circuit segments containing precision resistors allowing them to be accurately measured. Again refer to Figure 5.1.1 for proper value of each resistor. Refer to original data sheet that accompanies each instrument for factory readings.

OPERATIONAL CHECK ON POWER SUPPLIES:

Plate and Bias Supplies-

With a VTVM read the following test points. At the same time observe the ripple voltage with the oscilloscope and compare to the

HOLT INSTRUMENT LABORATORIES

PRECISION RESISTOR VALUES AVS-321

A.C. CONVERTER

R-103	2,667
R-104	200
R-105	3,333
R-324	305
R-301	10,000
R-302	10,000
R-320	10,000
R-321	10,000
R-322	435
R-401	100,000
R-402	50,000

ATTENUATOR

RANGE	RESISTANCE	RANGE	RESISTANCE
	Adjust R-325		
1.0	for 300 ohms	20.0	6,000
1.1	330	30.0	9,000
1.2	360	40.0	12,000
1.3	390	50.0	15,000
1.4	420	60.0	18,000
1.5	450	70.0	21,000
1.6	480	80.0	24,000
1.7	510	90.0	27,000
1.8	540	100.0	30,000
1.9	570	110.0	33,000
2.0	600	200.0	60,000
3.0	900	300.0	90,000
4.0	1,200	400.0	120,000
5.0	1,500	500.0	150,000
6.0	1,800	600.0	180,000
7.0	2,100	700.0	210,000
8.0	2,400	800.0	240,000
9.0	2,700	900.0	270,000
10.0	3,000	999.99+	300,000
11.0	3,300		

Figure 5.1.1

waveforms, Figures 5.1 through 5.10. The regulating ability of the 150 and 250 volt electronic regulators can be observed by lowering and then raising the line variac ten percent above and below the 115 volt operating point while monitoring the regulated voltages for loss of regulation. At 115 volt line voltage, check the following DC voltage Supplies:

C-201 B ..... 385 volts DC

V-202 pin 1 ..... 105 volts DC

C-203 B .....Neg. 200 volts DC

C-207 B ..... 410 volts DC

PL-203 pin 2 ..... 150 volts DC

PL-202 pin 1 ..... 250 volts DC

C-206 Terminal ..... + 6 volts DC

C-206 Can ..... - 6 volts DC

The damping voltage is measured between R-280 and R-249 on the underside of the AVS-321 chassis. Proper voltage lies between 12.0 and 15.0 volts DC. See original data sheet for factory readings.

READ ALL DC VOLTAGES:

With a VTVM read all DC tube voltages indicated on DC voltage charts Fig. 5.1 through 5.6. See original data sheet for factory readings.

CENTER FRONT PANEL METER FOR ONE VOLT RMS:

Connect a low distortion oscillator to the input terminals and monitor the input signal magnitude with a reliable meter. Set the oscillator for 1000 cycles and 1 volt RMS. The front panel meter on the AVS-321 should read 1 volt as well. The meter can be adjusted by turning the screw adjustment on the face of the meter movement.

ROUGH CHECK THE OUTPUT VOLTAGE:

Connect an AC meter capable of reading voltages up through 1000

volts, to the output terminals of the instrument with servo gain control turned fully counter-clockwise. With one volt input at 1000 cycles, select an output of one volt and read the output. Increase each decade switch in turn constantly watching the output. This check merely verifies the proper transformer connections and in no way is a calibration procedure.

PERFORM OPERATIONAL CHECKS ON THE SERVO AMPLIFIER AND AC CONVERTER:

If the DC voltages are normal throughout both the servo amplifier and the AC converter, placing the instrument in operate should cause the servo to seek its null point. If some malfunction still exists, use the following procedure. Turn the servo amplifier gain (R-118) fully counter-clockwise.

Check to see if one volt RMS is being fed to the input stage of the converter. With the oscilloscope, check the signal after either CR 301 or CR 302. The signal should be 28 to 33 volts peak to peak, each 180 degrees displaced from the other. The waveform should be as indicated in Fig. 5.21. If the portion along the reference line shows other than a smooth curve, as shown in the incorrect portion, then CR-301 and CR 302 should be checked and replaced. This irregularity will cause the frequency response to shift and also the output of the AVS-321 to become incorrect. The output of the filter as fed to the servo amplifier should be flat with a DC level of 3 to 4 volts depending on the position of the servo potentiometer.

If everything is operational up to this point, remove the chopper from its socket. Trace the filter output from the converter board through Z 102 to pin 1 of the chopper socket. Turn the servo gain counter-clockwise (OFF), stand-by switch to operate, with about one volt signal to the input terminals. With a VTVM read at pin 1 of chopper socket between 3 to 4 volts DC. Rotating servo gear clockwise

by hand will cause this voltage to rise. With a VTVM read the zener reference voltage at pin 8 of the reference oven (Z 101). The proper voltage is between 6 and 7 volts DC. The exact voltage is given in the test data sheets for each AVS-321. This is read by bucking 6 standard cells in series with a precision potentiometer and galvo to obtain the difference reading. The total of the cell voltages and potentiometer reading equals the zener voltage. Read the reference voltage at pin 3 of the chopper socket. Its value depends on the setting of R-104 but is between 3 and 4 volts DC. The exact voltage at time of calibration is given in the test data sheets. This is measured by the bucking method also but using only 3 cells. The negative lead for these measurements should be connected to TP 102, the upper test point. Reinsert the chopper and replace the cap. Be certain the chopper coil is being driven at 60 cycles at about $6\frac{1}{2}$ volts, and is properly sampling by observing its output with a scope at 10 milli-volt sensitivity, at pin 2 of the chopper socket. By pulling the servo gear about a quarter turn from null position, will produce a 60 cycle square wave of about 20 milli-volts peak to peak. It will have small spikes as shown in waveform page 5-15. The chopper output undergoes a voltage gain of approximately 1200 to the error signal test point, TP 101. If this gain is normal increase the servo gain adjustment (R 118) to the fully clockwise position. The servo should seek its null point and rapidly jitter when it gets there. Decrease the gain until the jittering stops.

Should the servo still fail to operate properly, disconnect the arm of the servo gain pot and connect a 60 cycle sinousoidal signal of about 15 milli-volts to pin 2 of V 102. With the motor rotor blocked, the transformer secondary voltage should be about 9 volts peak to peak and appear as a good sine wave. With the motor rotor

free, increase the signal at pin 2 from zero to 15 milli-volts. If the motor does not start to turn or it takes more than 15 milli-volts to start it, check the motor, gears and potentiometer for excessive mechanical friction. Let the input frequency drift one or two cycles above or below the line frequency. The servo motor should run first one way and then the other. When the motor is running the secondary of the transformer should rise to about 90 volts peak to peak.

READ HUM LEVEL:

Turn the servo gain completely counter-clockwise, place a 560 ohm resistor across the input terminals, select 290 volt output. Using the Hewlett Packard 330B, read the output, which is all hum, and it should be at least 60 db below the 290 volts.

READ AND MINIMIZE HARMONIC DISTORTION:

With the instrument operating at 10 volts nominal output, connect the Hewlett Packard 330B. Read the distortion at a number of frequencies between 35 cycles and 10,000 cycles. The total harmonic distortion should be less than .15% added to oscillator distortion. If necessary, adjust the distortion control on the power amplifier subassembly. Also check all tubes in amplifier and check output tubes for balance.

READ FEEDBACK LEVEL:

With no signal applied and the servo gain control turned completely counter-clockwise, disconnect the feedback lead in the power amplifier. Select 10 volts output and at various frequencies from 35 to 10,000 cycles gradually increase input level until output reaches 10 volts. (Caution: With no feedback the gain of the amplifier is considerably greater. As a result, about 0.1 volt input will produce the desired output. Never exceed the selected output.) Connect the feedback loop and read the new output voltage. The desirable level of attenuation

is between 17 and 20 db. See factory data sheet for original values. If necessary adjust feedback components to achieve this level. They are located at upper end of power output stage base plate.

CHECK AMPLIFIER STABILITY:

Connect the oscilloscope to the 250 volt regulated supply. Set the scope sensitivity for about one volt per centimeter. Rapidly and repeatedly switch the operate stand-by switch back and forth, observing the oscilloscope for any tendency toward sustained high frequency oscillations. Reconnect the oscilloscope to the output terminals and repeat the above procedure with the load switch set at 6 watts. The presence of oscillations are an indication of amplifier instability sometimes due to excessive feedback, or an incorrect adjustment of C 708.

SET AND COMPENSATE 1 VOLT RANGE FOR HIGH FREQUENCY:

To properly accomplish 1 volt calibration, a Holt Instrument Lab Model TV-1 Transfer Voltmeter is used in factory calibration. The 1 volt level is set with a 1000 cycle input signal, by adjusting the reference trim pot (R 104) so that the output exactly equals 1.0000 volt. The frequency response is then checked from 1000 cycles to 10,000 cycles. If at any point the output voltage varies in excess of 0.03%, the high frequency compensation can be adjusted. (R307, C307). These components have little or no effect on the output at 1000 cycles.

SET AND COMPENSATE FOR LOW FREQUENCY:

Connect a 1 KC signal to input. Set output voltage dial to any convenient level, 10 volts usually used. Connect output to a calibrated transfer voltmeter. Adjust R 325 trim pot, on the AC to DC converter board, so that the output is the same as selected by the dials. If the output varies out of specifications, adjust the low

frequency compensation (R 323, R 326, C 311). The low frequency compensation, although set at one particular voltage, holds for any output voltage. The adjustment of R 325 sets the 1000 cycle level of all voltages from 1.1 volts to 1000 volts. These voltages are controlled by the ratios of the precision attenuator resistors and should be within ± 0.05% of the attenuator setting at 1000 cycles.

ADJUST THE FREQUENCY, LEVEL AND DISTORTION OF THE 60 CYCLE INTERNAL OSCILLATOR:

Adjust the level until the front panel meter reads exactly one volt RMS. Then adjust the distortion control for minimum harmonic distortion at the output terminals. Since the level and distortion controls are in series there is some interaction. Subsequently, it may be necessary to adjust each alternately until the optimum is reached.

Connect the oscilloscope to pin 7 of V 210. Set the sweep for 60 cycle line sync. Adjust the frequency control (R 262). With the Hoit Instrument Lab. Model TV-1 connected to the output and the instrument operating at 10 volts from the internal oscillator, adjust until the output reaches 10.000 volts. If the oscillator becomes unstable before this point is achieved, it will be necessary to change the phase of the synchronizing voltage. A 90 degree shift is attained by interchanging R 281 and C 266. A 180 degree phase shift is possible by reversing the V 210 filament winding at the transformer.

POWER SUPPLY

WAVEFORMS

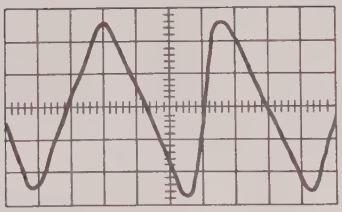


FIG. 5.1

C 201 B
0.2 V PER DIV.
2 MILLISEC PER DIV.

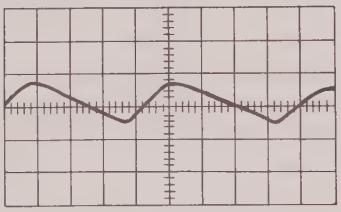


FIG. 5.2

V 202 PIN 1
.01 V PER DIV.
2 MILLISEC PER DIV.

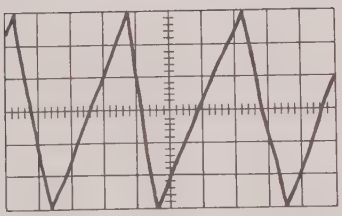


FIG. 5.3

C 203 B
0.2 V PER DIV.
5 MILLISEC PER DIV.

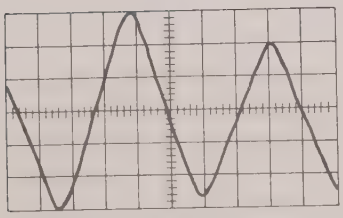


FIG. 5.4

C 207 B
0.5 V PER DIV.
2 MILLISEC PER DIV.

150 VOLT REGULATOR

WAVEFORMS

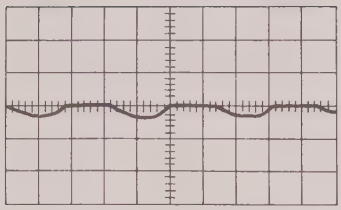


FIG. 5.5

PL 203 PIN 2
0.01 V PER DIV.
5 MILLISEC PER DIV.

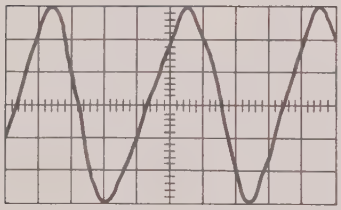


FIG. 5.6

V 213 PIN 6
0.01 V PER DIV.
2 MILLISEC PER DIV.

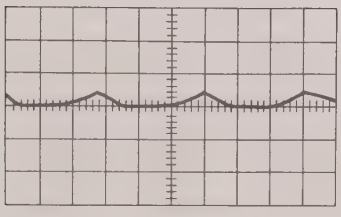


FIG. 5.7

V 208 PIN 2
0.01 V PER DIV.
5 MILLISEC PER DIV.

250 VOLT REGULATOR

WAVEFORMS

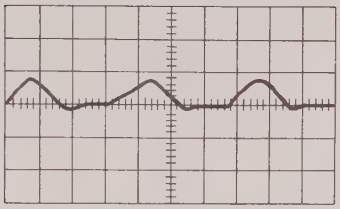


FIG. 5.8

PL 202 PIN 1
0.01 V PER DIV.
5 MILLISEC PER DIV.

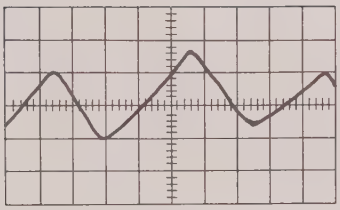


FIG. 5.9

V 212 PIN 6
0.02 V PER DIV.
2 MILLISEC PER DIV.

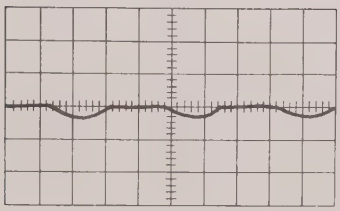


FIG. 5.10

V 205 PIN 2
0.01 V PER DIV.
5 MILLISEC PER DIV.

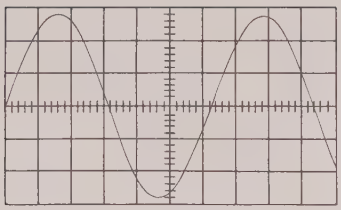


FIG. 5.11
V 703 PIN 7
1.2 V PEAK TO PEAK
SIGNAL FREQUENCY
* TAKEN WITH A LOW CAPACITY PROBE.

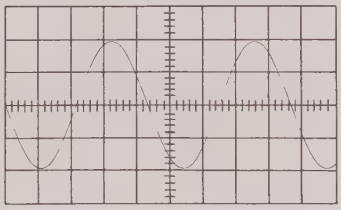


FIG. 5.12
V 703 PIN 6
AMPLITUDE BETWEEN 4 AND 6 VOLTS P. TO P. DEPENDENT ON FEEDBACK SIGNAL FREQUENCY
* TAKEN WITH A LOW CAPACITY PROBE.

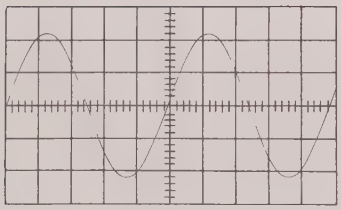


FIG. 5.13
V 704 PIN 6
22 V PEAK TO PEAK
SIGNAL FREQUENCY
* TAKEN WITH A LOW CAPACITY PROBE.

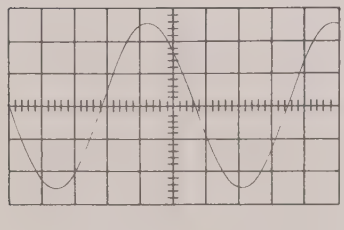


FIG. 5.14
V 705 PIN 6
250 V PEAK TO PEAK
SIGNAL FREQUENCY

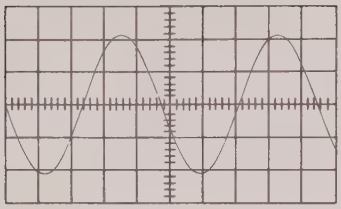


FIG. 5.15

V-706 Pin 8
240 Volts Peak to Peak
Signal Frequency

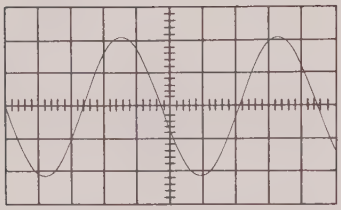


FIG. 5.16

V-709 Pin 8
V-710 Pin 8
215 Volts Peak to Peak
Signal Frequency

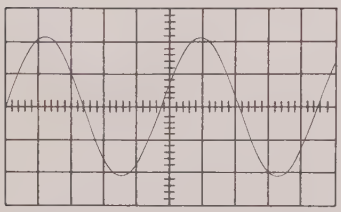


FIG. 5.17

V-709 Pin 3
V-710 Pin 3
215 Volts Peak to Peak
Signal Frequency

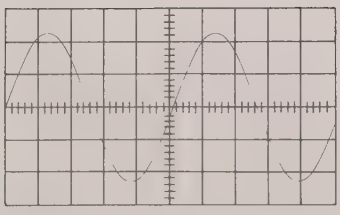


FIG. 5.18

V-703 Pin 8
.9 Volt Peak to Peak
Signal Frequency

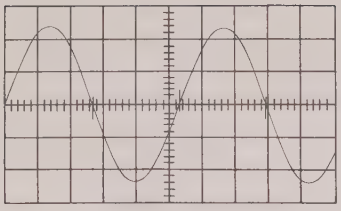


FIG. 5.19

V-302 Pin 5
1.4 Volts Peak to Peak
Signal Frequency
* Note spikes at zero crossover

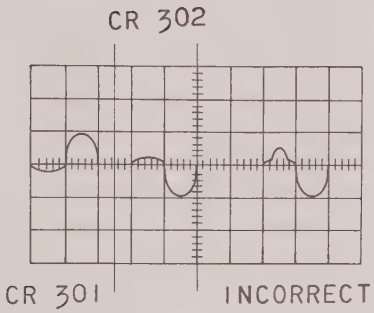


FIG. 5.20

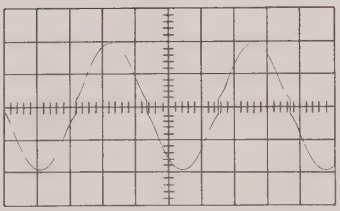


FIG. 5.21

V-304 Pins 3 & 6
76 volts Peak to Peak
Signal Frequency
* Note zero jumps.

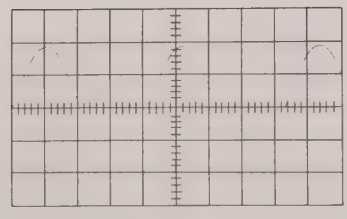


FIG. 5.22

T. P. 306
33 volts Peak to Peak
Signal Frequency

The following two waveforms are taken under test conditions. Normally the amplitude is a function of error amplitude and the wave form is actually distorted. However, it may become necessary to determine the operational capabilities of this stage. To do so follow this test procedure:

1. Unit in Standby
2. Chopper removed from its socket
3. A 10 millivolt peak to peak, 60 cycle signal applied at Pin 2 of V-101.

Following are the wave forms:

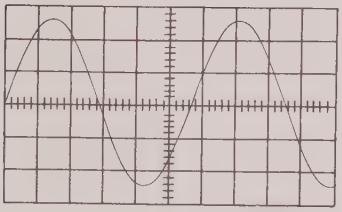


FIG. 5.23

V-101 Pin 1
.44 Volts Peak to Peak
60 cycles per sec.

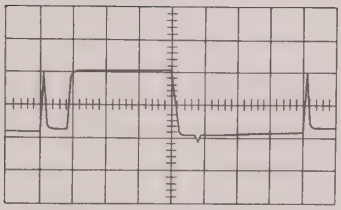


FIG. 5.24

PIN 2 CHOPPER
.01 VOLT PER DIV.
2 MILLISEC. PER DIV.

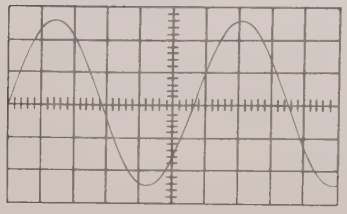


FIG. 5.25

V-101 Pin 6
9 Volts Peak to Peak
60 cycles per sec.

DC VOLTAGES
AC TO DC CONVERTER

FIG. 5.26

TUBE	TYPE	PIN NUMBERS								
		1	2	3	4	5	6	7	8	9
V101	12AX7	50	-.4	-.35	0	0	100	0	1.4	6.2
V102	12AX7	78	0	1.1	6.3 VAC	6.3VAC	75	0	1.1	0
V103	6AQ5	0	17	0	6.3 VAC	270	280	0		
V104	6AQ5	0	17	0	6.3 VAC	270	280	0		

DC VOLTAGES
SERVO AMPLIFIER

FIG. 5.27

TUBE	TYPE	PIN NUMBERS								
		1	2	3	4	5	6	7	8	9
V301	6136	-2.5	0	0	-6.0	110	150	0		
V302	6AU6	-2.0	0	0	6.3 VAC	85	150	0		
V303	6AU6	-2.0	0	0	6.3 VAC	110	150	0		
V304	5687	245	110	115	6.3 VAC	6.3VAC	115	110	0	245

DC VOLTAGES
PRE-AMPLIFIER

FIG. 5.28

TUBE	TYPE	PIN NUMBERS								
		1	2	3	4	5	6	7	8	9
V701	6AB4	245	NC	6.3VAC*	0*	245	0	4.3		
V702	0B2	NC	NC	NC	NC	0	NC	-105		
V703	12AX7	109	-.7	0	0*	0*	97	0	1.3	6.3VAC*
V704	12AU7	215	-7**	100	0*	0*	206	-7**	100	6.3VAC*
V705	12AU7	300	0	17	0*	0*	300	0	17	6.3VAC*
V706	12AX7	410	-33	-32	0*	0*	410	-33	-32	6.3VAC*

*Measured from Pin 4 V703
**Measured from Pin 3 V703

DC VOLTAGES
POWER AMPLIFIER

FIG. 5.29

TUBE	TYPE	PIN NUMBERS								
		1	2 to 7	3	4	5	6	7	8	9
V707	5881	NC	6.3 AC	410	405	-32	NC	4.5	3.5*	
V708	5881	NC	6.3 AC	410	405	-32	NC	4.5	3.5*	
V709	5881	NC	6.3 AC	410	405	-32	NC	4.5	3.5*	
V710	5881	NC	6.3 AC	410	405	-32	NC	4.5	3.5*	

*Measured across 50 ohm cathode resistor with signal input.

DC VOLTAGES
+ 150 AND + 250 REGULATORS

FIG. 5.30

TUBE	TYPE	PIN NUMBERS								
		1	2	3	4	5	6	7	8	9
V205	12AX7	83	-.12	.67	0	0	135	0	0	6.3VAC
V212	12AV7	95	-3.5	0	0	0	137	-3.5	0	6.3VAC
V203	12AV7	270	137 .8*	137 1.4*	0	0	270	137 .8*	137 1.4*	6.3VAC
V209	12AV7	270	137 .8*	137 1.4*	0	0	270	137 .8*	137 1.4*	6.3VAC
V208	12AX7	83	-1.3***	-19	0	0	135	-1.3***	-19	6.3VAC
V213	12AV7	95	-3.5	0	0	0	137	-3.5	0	6.3VAC
V206	12AV7	270	43 -1.5**	46 1.4**	0	0	270	43	46 1.4**	6.3VAC

NOTE: All measured from Pin 3, V212 or V213 except those listed below:

* Measured from Pin 6 V205
** Measured from Pin 2 PL203
*** Measured from Pin 3 V208

DC VOLTAGES
60 CYCLE OSCILLATOR

FIG. 5.31

TUBE	TYPE	PIN NUMBERS								
		1	2	3	4	5	6	7	8	9
V210	6AU6	3.8	7.1			119	148	7.1		
V211	5687	230	100	122			3.7		105	104

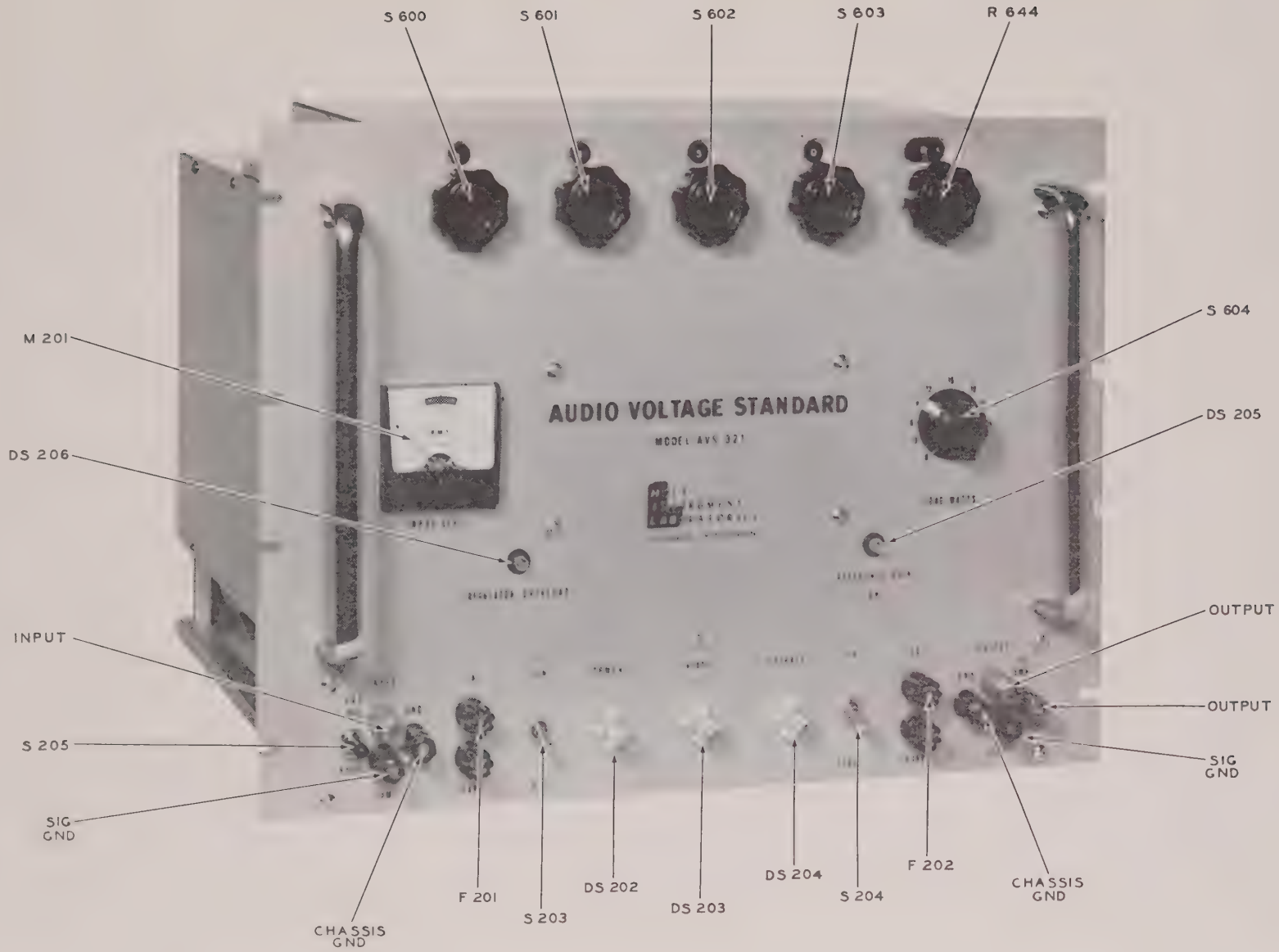

S 600
S 601
S 602
S 603
R 644
S 604
M 201
DS 205
DS 206
AUDIO VOLTAGE STANDARD
MODEL AVS 321
INPUT
OUTPUT
OUTPUT
S 205
SIG GND
SIG GND
F 201
S 203
DS 202
DS 203
DS 204
S 204
F 202
CHASSIS GND
CHASSIS GND

FIG. 6.1

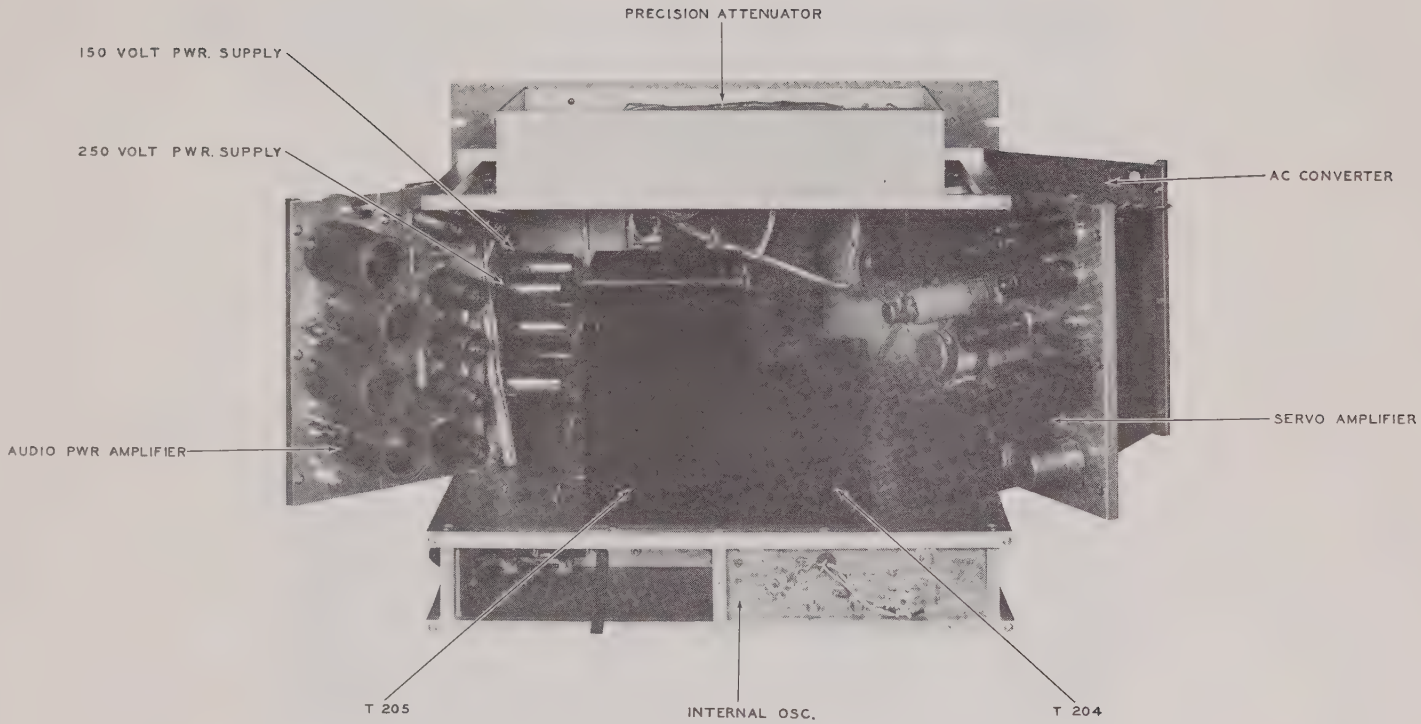

PRECISION ATTENUATOR
150 VOLT PWR. SUPPLY
250 VOLT PWR. SUPPLY
AC CONVERTER
SERVO AMPLIFIER
AUDIO PWR AMPLIFIER
T 205
INTERNAL OSC.
T 204

FIG. 6.2

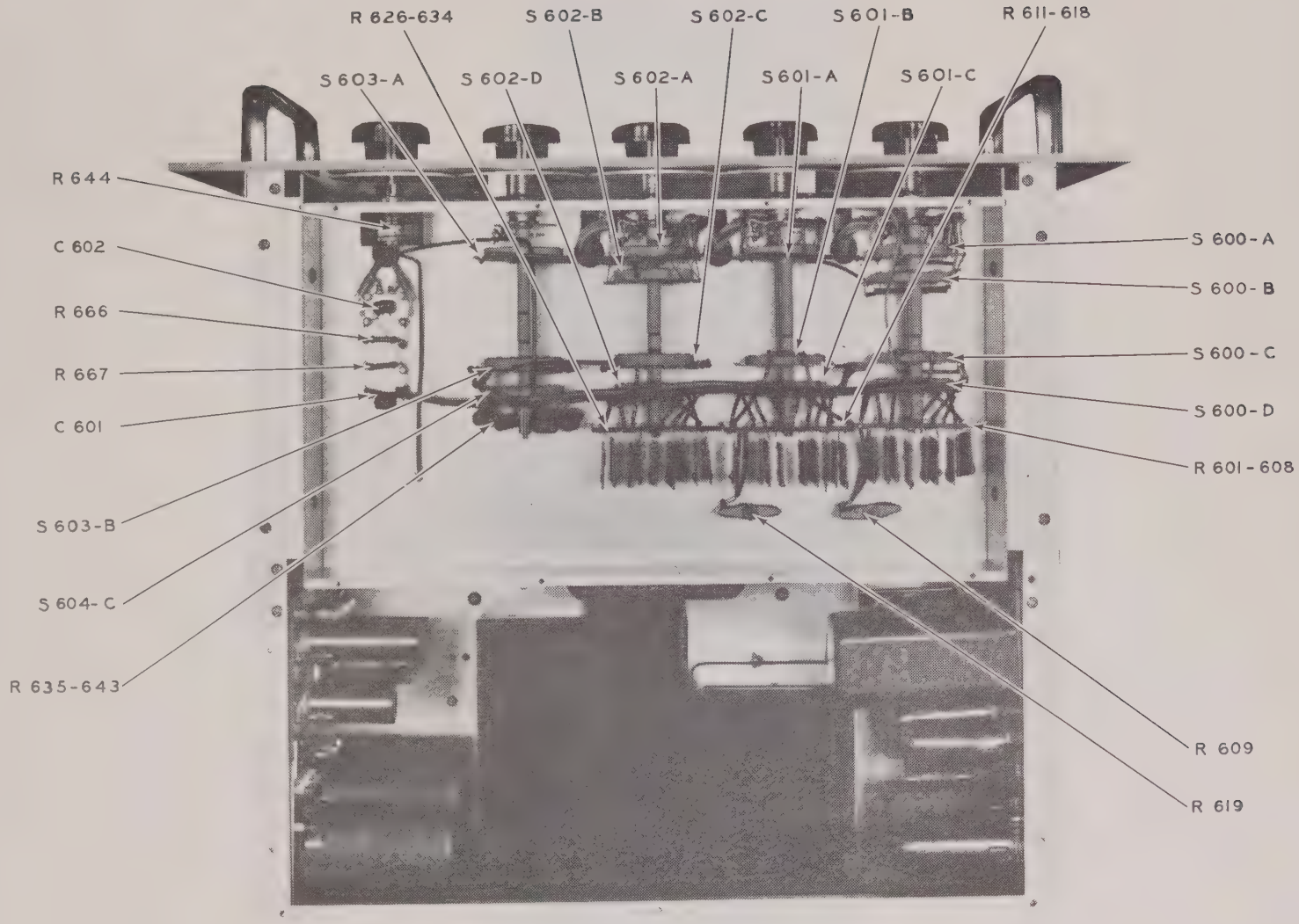

R 626-634
S 602-B
S 602-C
S 601-B
R 611-618
S 603-A
S 602-D
S 602-A
S 601-A
S 601-C
R 644
C 602
R 666
R 667
C 601
S 603-B
S 604-C
R 635-643
S 600-A
S 600-B
S 600-C
S 600-D
R 601-608
R 609
R 619

FIG. 6.3

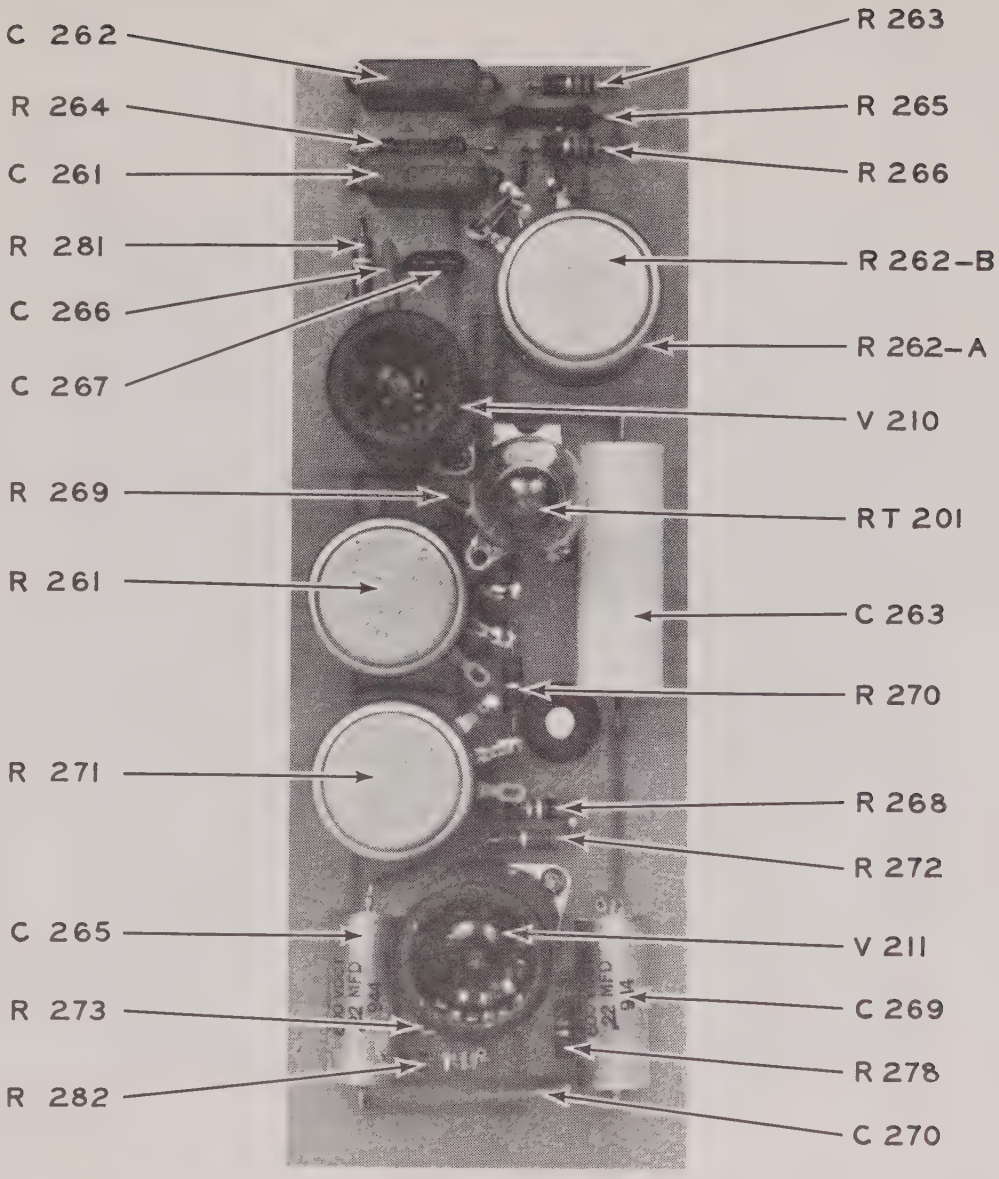

C 262
R 264
C 261
R 281
C 266
C 267
R 269
R 261
R 271
C 265
R 273
R 282
R 263
R 265
R 266
R 262-B
R 262-A
V 210
RT 201
C 263
R 270
R 268
R 272
V 211
C 269
R 278
C 270

FIG. 6.4

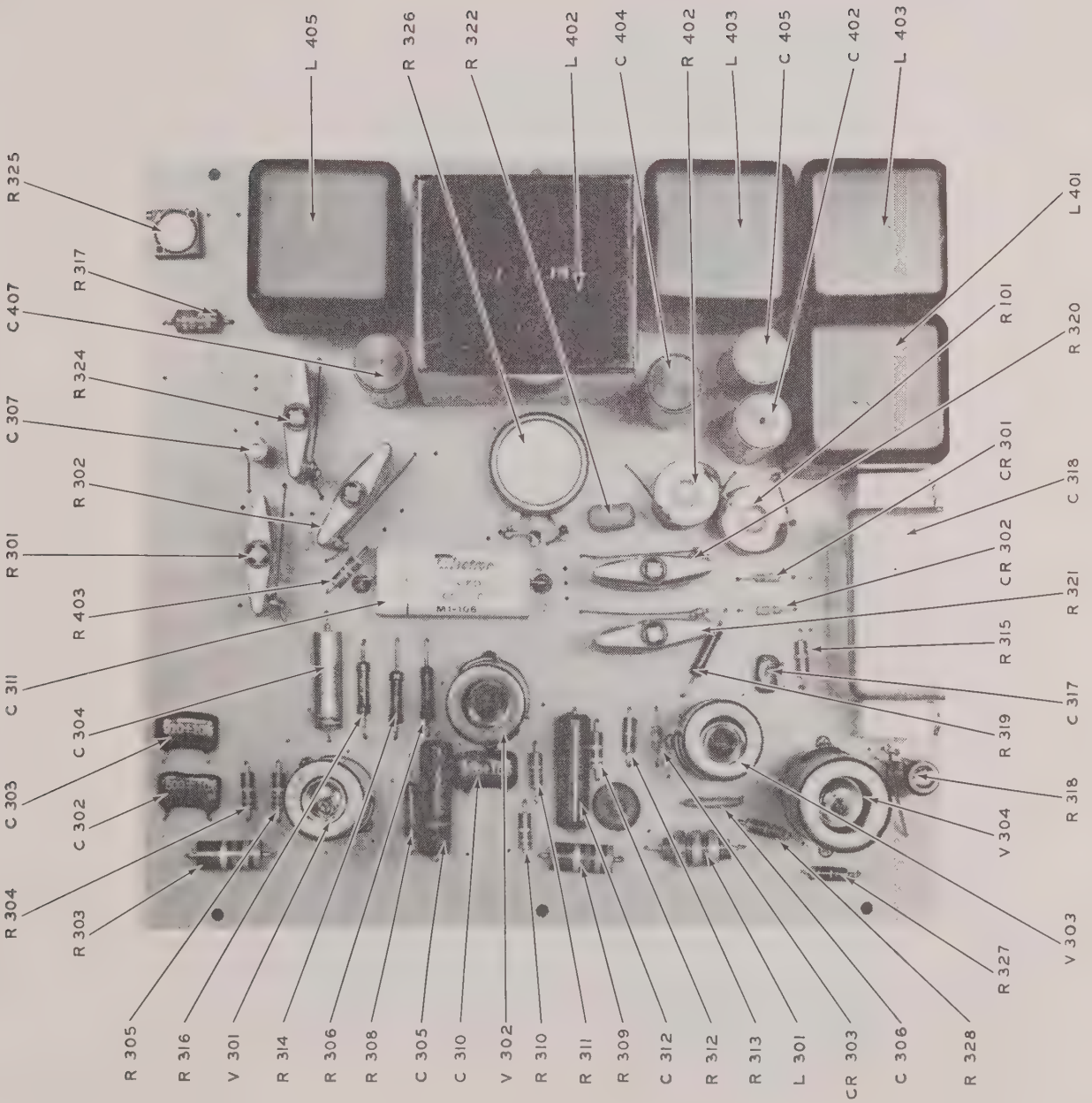

L 405
R 326
R 322
L 402
C 404
R 402
L 403
C 405
C 402
L 403
R 325
R 317
C 407
R 324
C 307
R 302
R 301
R 403
C 311
C 304
C 303
C 302
R 304
R 303
L 401
R 101
R 320
CR 301
C 318
CR 302
R 321
R 315
C 317
R 319
R 318
V 304
V 303
R 327
R 305
R 316
V 301
R 314
R 306
R 308
C 305
C 310
V 302
R 310
R 311
R 309
C 312
R 312
R 313
L 301
CR 303
C 306
R 328

FIG. 6.5

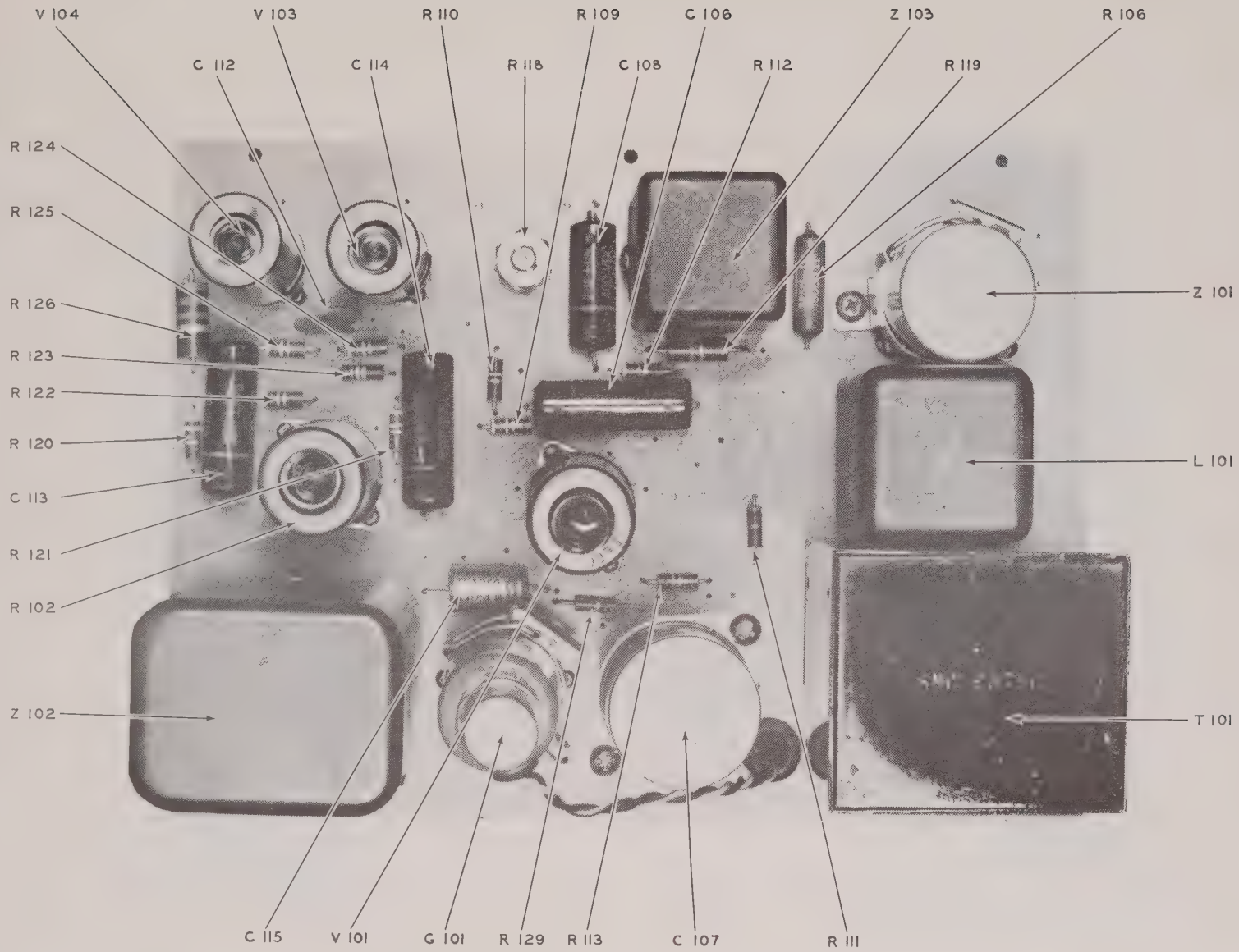

V 104
V 103
R 110
R 109
C 106
Z 103
R 106
C 112
C 114
R 118
C 108
R 112
R 119
R 124
R 125
R 126
R 123
R 122
R 120
C 113
R 121
R 102
Z 102
Z 101
L 101
T 101
C 115
V 101
G 101
R 129
R 113
C 107
R 111

FIG. 6.6

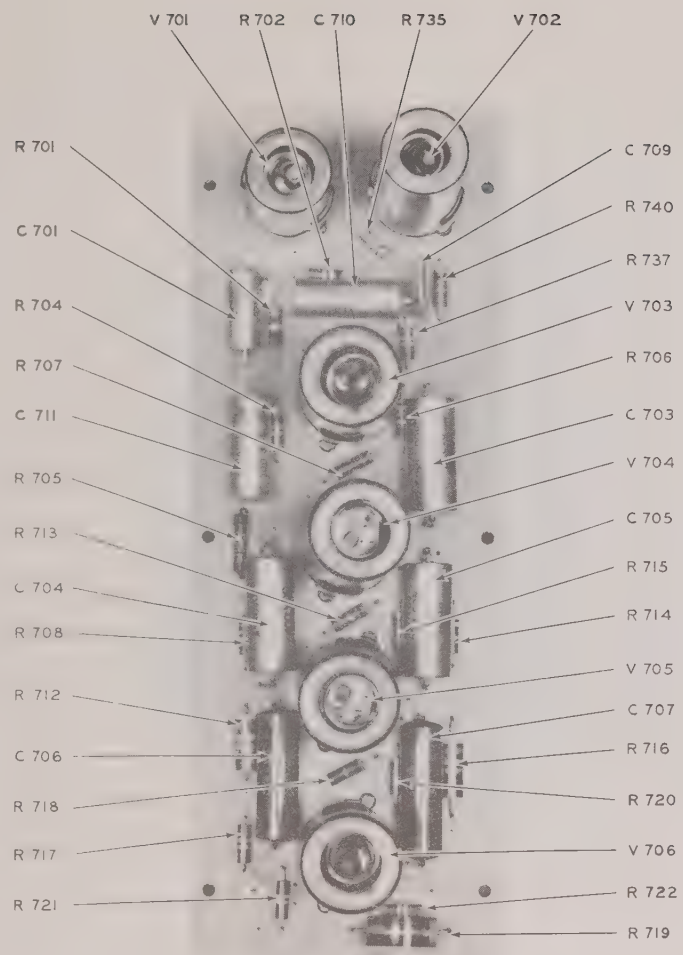

V 701
R 702
C 710
R 735
V 702
R 701
C 701
R 704
R 707
C 711
R 705
R 713
C 704
R 708
R 712
C 706
R 718
R 717
R 721
C 709
R 740
R 737
V 703
R 706
C 703
V 704
C 705
R 715
R 714
V 705
C 707
R 716
R 720
V 706
R 722
R 719

FIG. 6.7

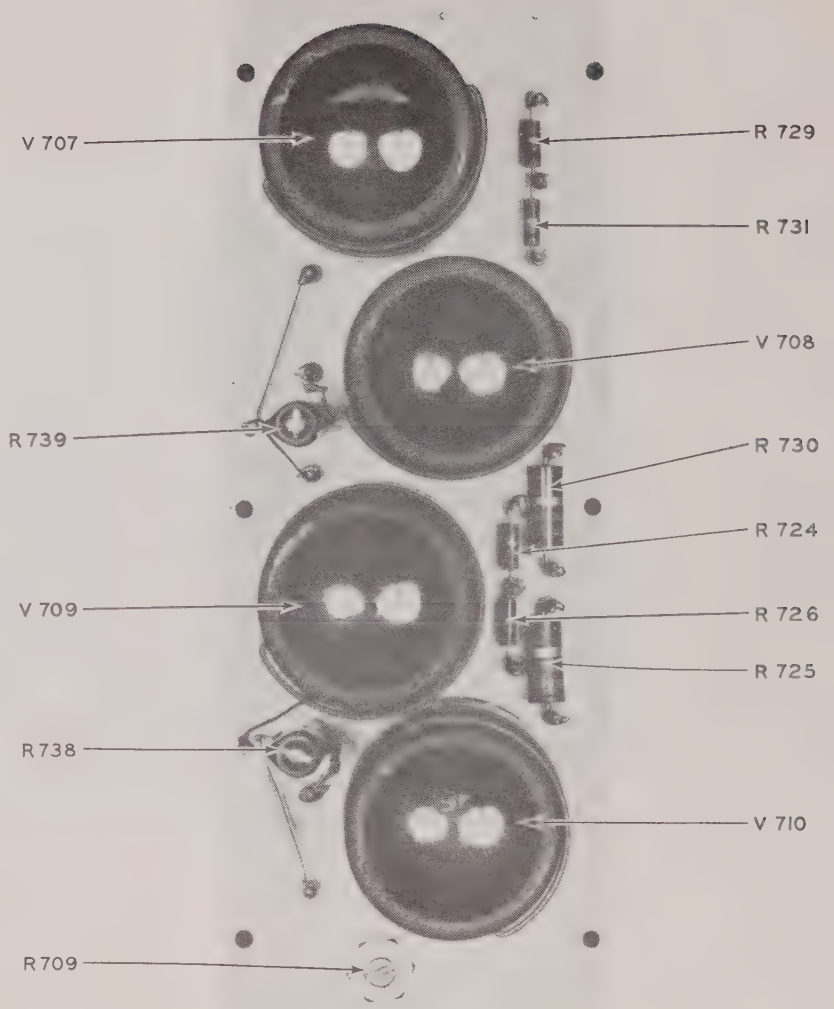

V 707
R 729
R 731
V 708
R 739
R 730
R 724
V 709
R 726
R 725
R 738
V 710
R 709

FIG. 6.8

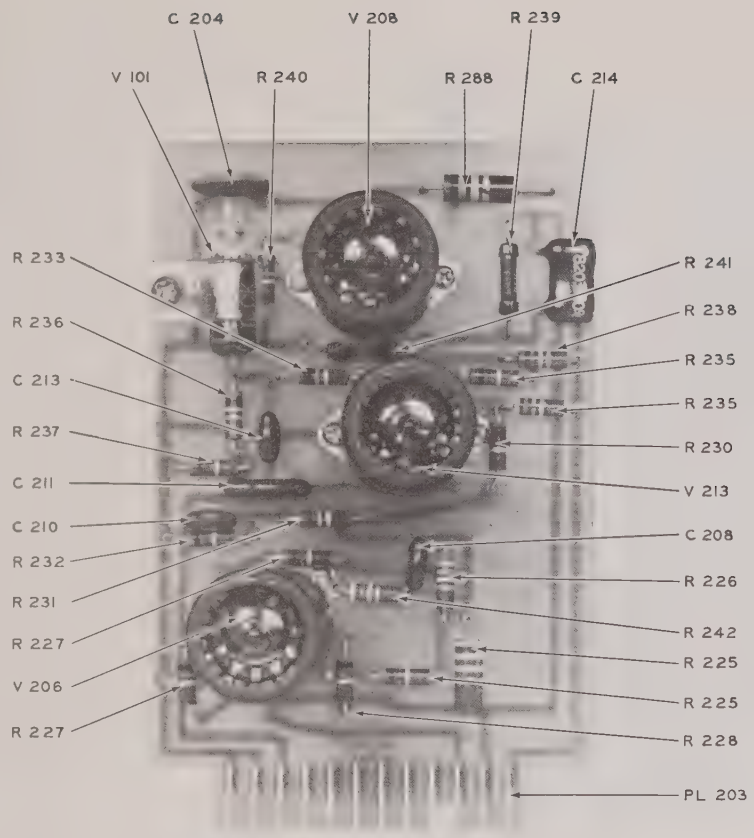


FIG. 6.9

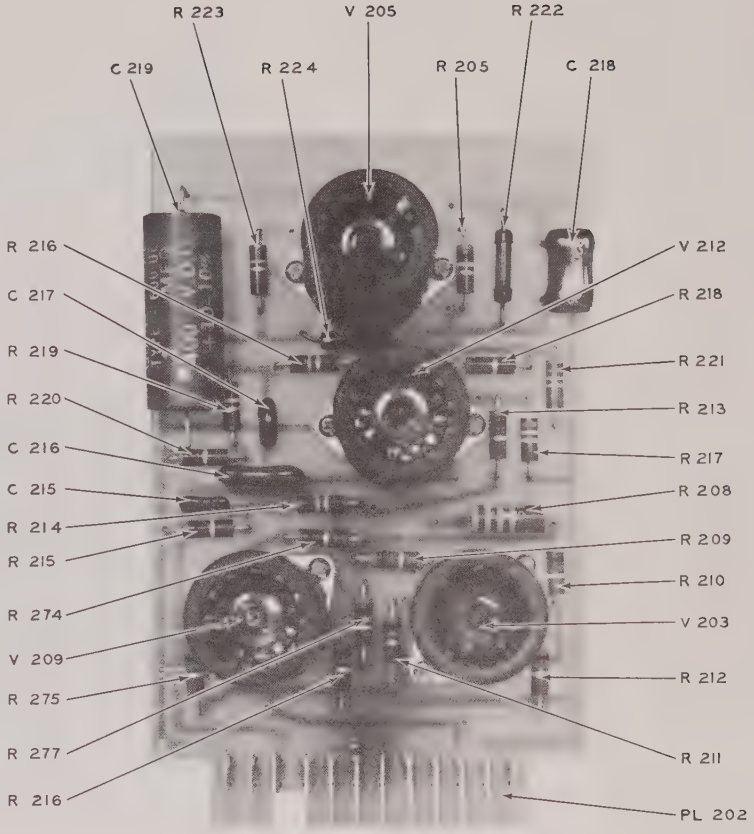


FIG. 6.10

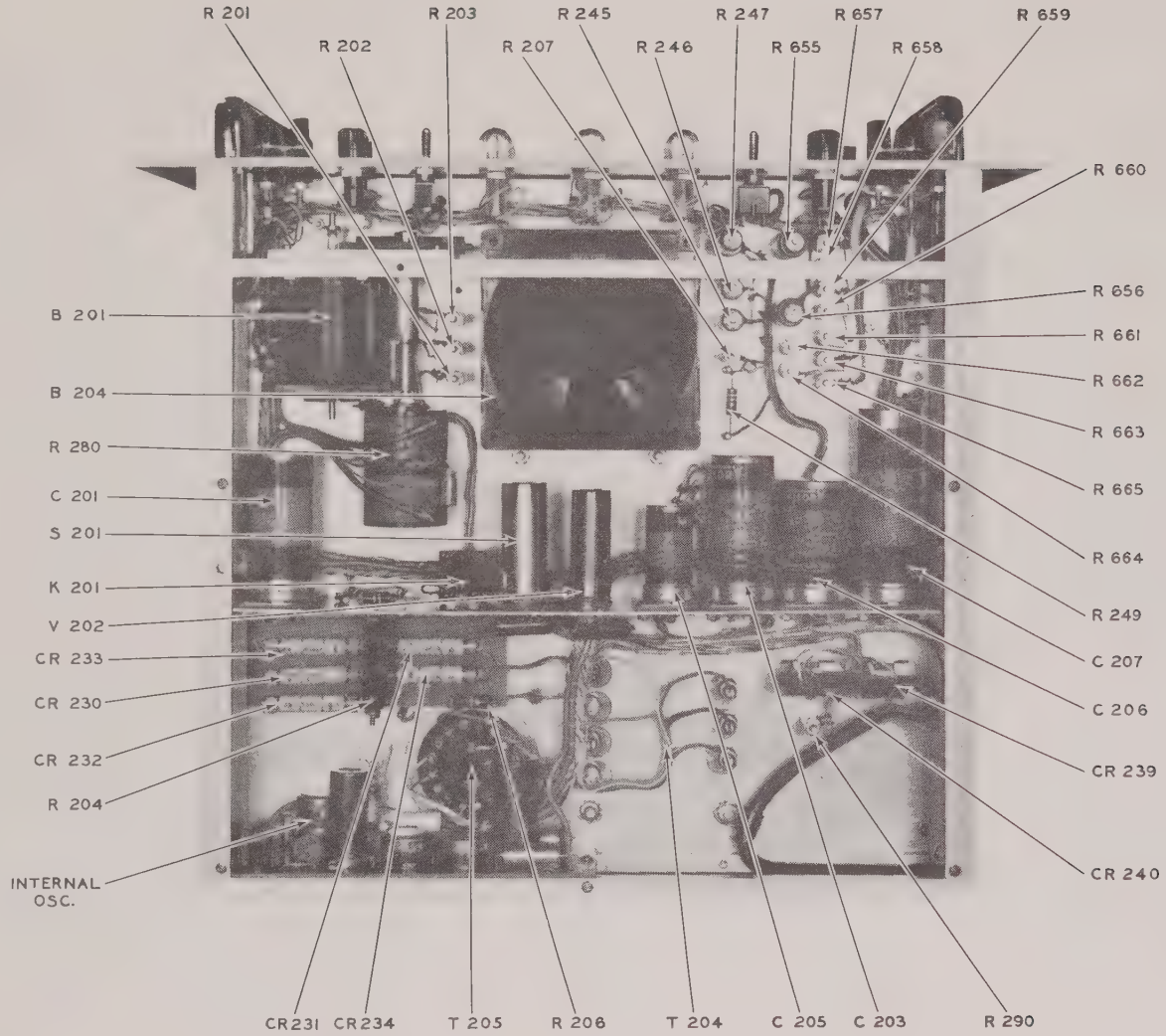

R 201
R 202
R 203
R 245
R 207
R 246
R 247
R 655
R 657
R 658
R 659
R 660
R 656
R 661
R 662
R 663
R 665
R 664
R 249
C 207
C 206
CR 239
CR 240
B 201
B 204
R 280
C 201
S 201
K 201
V 202
CR 233
CR 230
CR 232
R 204
INTERNAL OSC.
CR231
CR234
T 205
R 208
T 204
C 205
C 203
R 290

FIG. 6.11

INSTRUCTIONS FOR ORDERING PARTS

Standard parts can be purchased from Holt Instrument Laboratories or obtained locally.

In addition to the standard parts, there are necessarily some special parts that are made by Hi-Lab or for Hi-Lab. These are most easily obtained by ordering direct from Holt Instrument Laboratories.

When ordering, please include all the information in the replacement parts list, model number and serial number of the unit.

ELECTRONICS PARTS REFERENCE DESIGNATIONS

CP	Adapter, connector
A	Amplifier (other than rotating)
E	Antenna; aerial
A	Assembly
AT	Attenuator
DS	Audible signaling device
T	Autotransformer
BY	Battery
E	Bimetallic strip
TB	Block, connecting
B	Blower, fan, motor, prime mover
TB	Board, terminal
CB	Breaker, circuit
DS	Buzzer
W	Cable
C	Capacitor
E	Cell, aluminum or electrolytic
V	Cell, light-sensitive, photo-emissive, or photo conductive
N	Chart
I	Choke
CB	Circuit breaker
M	Clock
HY	Coil, hybrid
L	Coil, induction, loading, relay operating, retardation, tuning
J	Connector, receptacle, electrical (with male, female or male & female contacts and designed to be mounted on a bulkhead, wall, chassis or panel)
P	Connector, plug, electrical (with male, female or male & female contacts, constructed to be affixed to the end of a cable, conduit, coaxial line, cord or wire)
K	Contactor (electrically operated)
S	Contactor (mechanically or thermally operated)
M	Counter (indicating device)
CR	Crystal detector
CR	Crystal diode
Y	Crystal, piezoelectric
CR	Crystal unit
S	Cutout, thermal
CR	Detector, crystal
DS	Device, indicating (except meter or thermometer)
V	Electron tube
B	Fan
FL	Filter
DS	Flasher
F	Fuse
X	Fuseholder (see 5.6.1)
H	Hardware; bolts; nuts; screws
HR	Heater (element for thermostat, oven, etc.)
HY	Hybrid coil or junction
DS	Indicator
L	Inductor
MP	Interlock, mechanical
S	Interlock, safety, electrical
RT	Lamp, ballast
HR	Lamp, heating
DS	Lamp, illuminating
DS	Lamp, pilot
RT	Lamp, resistance
DS	Lamp, signal
X	Lampholder
LS	Loudspeaker
MP	Mechanical part
M	Meter
B	Motor
MP	Mounting (not in electrical circuit and not a socket)

N	Nameplate
Z	Network, general (where specific letters do not fit, when considered as a part)
AT	Pad
E	Part, miscellaneous electrical
R	Potentiometer
A	Power supply; source of power
-	Receptacle (Connector, fixed)
CR	Rectifier, crystal or metallic
VR	Regulator, voltage (except an electron tube)
MP	Reed, vibrating
K	Relay (electrically operated contactor or switch)
R	Resistor
RT	Resistor, current regulating
R	Resistor, variable
R	Rheostat
CR	Selenium cell
E	Shield, electrical
R	Shunt
X	Socket (see 5.6.1)
L	Solenoid
LS	Speaker; loudspeaker
TB	Strip, terminal
S	Switch (mechanically or thermally operated)
*TP	Test point
RT	Thermistor
TC	Thermo-couple
M	Thermometer
S	Thermostat
M	Timer
MT	Transducer
T	Transformer
Q	Transistor
V	Tube, electron
Z	Tuned Circuit
CR	Varistor, asymmetrical
RV	Varistor, Symmetrical
G	Vibrator, interrupting
DS	Visual signaling device
VR	Voltage regulator (except electron tube)

LIST OF CODE LETTERS USED IN TABLE OF REPLACEABLE PARTS TO DESIGNATE THE MANUFACTURERS

AC	Astron Corp.	E. Newark, N.J.
AEO	Aerovox Corp.	New Bedford, Mass.
AH&H	Arrow-Hart & Hegeman	Hartford 6, Conn.
AMP	Amperite Co.	New York 12, N.Y.
ASW	American Spring & Wire	Chicago, Ill.
B L	Bowmar Inst. Lab	Fort Wayne, Ind.
C	Centralab	Milwaukee, Wis.
COR	Cornish Wire Co.	New York 7, N.Y.
DA	Daven	Livingston, N.J.
DP	Daystrom Pacific	Los Angeles, Calif.
DR	Drake	Chicago, Ill.
EI	Electro Instruments, Inc.	San Diego, Calif.
ELD	Eldema Corp.	El Monte, Calif.
EM	Arco-Elmenco	New York 13, N.Y.
EP	Electron Prod.	Pasadena, Calif.
GA	Good-All Electric Mfg. Co.	Ogallala, Nebr.
GE	General Electric	Schenectady, N.Y.
GR	General Radio	West Concord, Mass.
GU	Guardian Electric	Chicago, Ill.
H L	Holt Instrument Lab	Oconto, Wis.
HO	Hoffman Semi-Conductor	Evanston, Ill.
H	Hughes Semi-Conductor Corp.	Oceanside, Calif.
	International Rectifier Corp.	El Segundo, Calif.
IRC	International Resistance Co.	Philadelphia 8, Pa.
	James Vibrapowr	Chicago, Ill.

LB	Libert Bearing	Green Bay, Wis.
LF	Little Fuse	Des Plaines, Ill.
MAL	Mallory & Co.	Indianapolis 6, Ind.
NE	Northern Engineering Lab	Burlington, Wis.
OM	Oak Mfg. Co.	Chicago, Ill.
OHM	Ohmite	Skokie, Ill.
RAY	Raytheon	Newton, Mass.
RO	Rotron Mfg. Co.	Woodstock, N.Y.
SA	Sage Electronics	East Rochester, N.Y.
SC	Switchcraft	Chicago 30, Ill.
SE	Spectrol Electronics	San Gabriel, Calif.
SNC	SNC Transformer Corp.	Oshkosh, Wis.
SO	Southern Electronics	Burbank, Calif.
SP	Sprague	North Adams, Mass.
ST	Sarkes Tarzian	Bloomington, Ill.
STA	Stancor	Chicago, Ill.
TO	Topaz Products, Inc.	San Diego, Calif.
WE	Weston	Newark, N.J.

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. & Mfr. Designation
B 201	Motor, Servo 2 Phase	HIL FPE-2512
B 204	Fan, Venturi, 115 VAC 60 cps, Single Phase	RO Venturi
C 101	Capacitor, Fixed, Mylar Paper, .05 MFD, 400 VDCW, Inclosed in Z 102	SP 4 TM-S5-.05
C 102	Capacitor, Fixed, Mylar Paper, .05 MFD, 400 VDCW, Inclosed in Z 102	SP 4 TM-S5-.05
C 103	Capacitor, Fixed, Metalyte 1 MFD, 200 VDCW, Inclosed in Z 102	AC ML-2-1
C 105	Capacitor, Fixed, Metallized Paper .1 MFD, 200 VDCW	AEO P-123 Z-.1
C 106	Capacitor, Fixed, Mylar Paper .05 MFD, 400 VDCW	SP 4 TM-S5-.05
C 107	Capacitor, Fixed, Triple Section Electrolytic 20-20-40 MFD, 250 VDCW	M FP 320
C 108	Capacitor, Fixed, Mylar Paper .05 MFD, 400 VDCW	SP 4 TM-S5-.05
C 109	Capacitor, Fixed, Silvered Mica 5600 MFD, 500 VDCW, ± 2% Inclosed in Z 103	EM CM-30-5600
C 110	Capacitor, Fixed, Silvered Mica 5600 MFD, 500 VDCW, ± 2% Inclosed in Z 103	EM CM-30-5600
C 111	Capacitor, Fixed, Silvered Mica 11200 MMFD (2,-5600 MMF in Parallel) 500 VDCW, ± 2% Inclosed in Z 103	EM CM-30-11200
C 112	Capacitor, Fixed, Disc .01 MFD, 600 VDCW	C DD6-103-.01
C 113	Capacitor, Fixed, Mylar Paper .05 MFD, 400 VDCW	SP 4 TM-S5-.05
C 114	Capacitor, Fixed, Mylar Paper .05 MFD, 400 VDCW	SP 4 TM-S5-.05
C 115	Capacitor, Fixed, Electrolytic 110 MFD, 3 VDCW	SP TE-1060-110
C 116	Capacitor, Fixed, Disc .01 MFD, 600 VDCW	C DD6-103-.01

Circuit Ref.	Description	Mfr. & Mfr. Designation
C 201	Capacitor, Fixed, Electrolytic Double Section, 40-40 MFD, 450 VDCW	MAL FP-238
C 202	Capacitor, Fixed, Mylar Paper .05 MFD, 400 VDCW	SP 4 TM-S5-.05
C 203	Capacitor, Fixed, Electrolytic Double Section, 40-40 MFD, 450 VDCW	MAL FP-238
C 204	Capacitor, Fixed, Disc .01 MFD, 600 VDCW	C DD6-103-.01
C 205	Capacitor, Fixed, Single Electrolytic 50 MFD, 150 VDCW	MAL FP 115-50
C 206	Capacitor, Fixed, Electrolytic, Metal CAD, 2000 MFD, 15 VDCW	MAL WP-041-2000
C 207	Capacitor, Fixed, Electrolytic, Triple Section, 80-40-20 MFD, 450 VDCW	MAL FP 378
C 208	Capacitor, Fixed, Dur-Mica 100 MFD, 500 VDCW, ± 10%	EM DM-15-100
C 209	Capacitor, Fixed, Dur-Mica 100 MFD, 500 VDCW, ± 10%	EM DM-15-100
C 210	Capacitor, Fixed, Dur-Mica 15 MMFD, 500 VDCW, ± 10%	EM DM-15-15
C 211	Capacitor, Fixed, Dur-Mica 1200 MMFD, 500 VDCW, ± 10%	EM DM-19-1200
C 213	Capacitor, Fixed, Dur-Mica 100 MMFD, 500 VDCW, ± 10%	EM DM-15-100
C 214	Capacitor, Fixed, Dur-Mica 820 MMFD, 500 VDCW, ± 10%	EM DM-19-820
C 215	Capacitor, Fixed, Dur-Mica 15 MMFD, 500 VDCW, ± 10%	EM DM-15-15
C 216	Capacitor, Fixed, Dur-Mica 1200 MMFD, 500 VDCW, ± 10%	EM DM-19-1200
C 217	Capacitor, Fixed, Dur-Mica 100 MMFD, 500 VDCW, ± 10%	EM DM-15-100
C 218	Capacitor, Fixed, Dur-Mica 820 MMFD, 500 VDCW, ± 10%	EM DM-19-820

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. & Mfr. Designation
C 219	Capacitor, Fixed, Mylar Dielectric .2 MFD, 400 VDCW	GA 600-JE-.2
C 220	Capacitor, Fixed, Electrolytic 15 MFD, 25 VDCW	SP TE 1205-15
C 260	Capacitor, Fixed, Electrolytic 15 MFD, 25 VDCW	SP TE 1205-15
C 261	Capacitor, Fixed, Dur-Mica 5600 MMFD, 500 VDCW, ± 10%	EM CM-30-5600
C 262	Capacitor, Fixed, Dur-Mica 5600 MMFD, 500 VDCW, ± 10%	EM CM-30-5600
C 263	Capacitor, Fixed, Metallized Paper 2.5 MFD, 400 VDCW	EP M4-255-2.5
C 265	Capacitor, Fixed, Metallized Paper .22 MFD, 400 VDCW	AEO P123Z-.22
C 266	Capacitor, Fixed, Disc .01 MFD, 600 VDCW	C DD6-103-.01
C 267	Capacitor, Fixed, Dur-Mica 75 MMFD, 500 VDCW, ± 10%	EM DM-15-75
C 268	Capacitor, Fixed, Mylar Paper .05 MFD, 400 VDCW	SP 4 TM-S5-.05
C 269	Capacitor, Fixed, Metallized Paper .22 MFD, 400 VDCW	AEO P-123Z-.22
C 270	Capacitor, Fixed, Disc .01 MFD, 600 VDCW	C DD6-103-.01
C 302	Capacitor, Fixed, Dur-Mica 1500 MMFD, 300 VDCW, ± 10%	EM DM-19-1500
C 303	Capacitor, Fixed, Dur-Mica 910 MMFD, 300 VDCW, ± 10%	EM DM-19-910
C 304	Capacitor, Fixed, Metallized Paper .22 MFD, 200 VDCW	AEO P123Z-.22
C 305	Capacitor, Fixed, Mylar Paper .01 MFD, 400 VDCW	SP 4 TM-S1-.01
C 306	Capacitor, Fixed, Disc .01 MFD, 600 VDCW	C DD6-103-.01
C 307	Capacitor, Trimmer, Tubular 1 - 7.5 MMFD, 600 VDCW	C 829-7-1-7.5

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. & Mfr. Designation
C 309	Capacitor, Fixed, Dur-Mica 1200 MMFD, 300 VDCW	EM DM-19-1200
C 310	Capacitor, Fixed, Dur-Mica 910 MMFD, 300 VDCW	EM DM-19-910
C 311	Capacitor, Fixed, Metallized Paper Valve varies with unit	EP
C 312	Capacitor, Fixed, Mylar Paper .01 MFD, 400 VDCW	SP 4 TM-S1-.01
C 317	Capacitor, Fixed, Dur-Mica 430 MMFD, 500 VDCW, ± 10%	EM DM-15-430
C 318	Capacitor, Fixed, Mylar 5 MFD, 200 VDCW, ± 10%	SO MY-5-10-200 E-
C 320	Capacitor, Fixed, Ceramic Factory selected value	C TCZ
C 321	Capacitor, Fixed, Ceramic Factory selected value	C TCZ
C 401	Capacitor, Fixed, Mylar .22 MFD, 100 VDCW, ± 1%	GA 663 UW-.22
C 402	Capacitor, Fixed, Mylar .275 MFD, 100 VDCW, ± 1%	GA 620 UPB-.275
C 403	Capacitor, Fixed, Mylar .043 MFD, 100 VDCW, ± 1%	GA 663 UW-.043
C 404	Capacitor, Fixed, Mylar .35 MFD, 100 VDCW, ± 1%	GA 620 UPB-.35
C 405	Capacitor, Fixed, Mylar .35 MFD, 100 VDCW, ± 1%	GA 620 UPB-.35
C 406	Capacitor, Fixed, Mylar .033 MFD, 200 VDCW, ± 1%	GA 663 UW-.033
C 407	Capacitor, Fixed, Mylar .275 MFD, 100 VDCW, ± 1%	GA 620 UPB-.275
C 408	Capacitor, Fixed, Mylar .22 MFD, 100 VDCW, ± 1%	GA 663-UW-.22
C 601	Capacitor, Fixed, Dur-Mica 360 MMFD, 300 VDCW	EM DM-15-360

Circuit Ref.	Description	Mfr. & Mfr. Designation
C 602	Capacitor, Fixed, Dur-Mica 620 MMFD, 300 VDCW	EM DM-19-620
C 603	Capacitor, Fixed, Dur-Mica 620 MMFD, 500 VDCW	EM DM-19-620
C 604	Capacitor, Fixed, Dur-Mica 500 VDCW, Factory selected value, About 160 MMFD	EM DM-15
C 703	Capacitor, Fixed, Metallized Paper .22 MFD, 400 VDCW	AEO P 123Z-.22
C 704	Capacitor, Fixed, Metallized Paper .22 MFD, 400 VDCW	AEO P 123Z-.22
C 705	Capacitor, Fixed, Metallized Paper .22 MFD, 400 VDCW	AEO P 123Z-.22
C 706	Capacitor, Fixed, Metallized Paper .02 MFD, 400 VDCW	MAL GEM-612-.02
C 707	Capacitor, Fixed, Metallized Paper .02 MFD, 400 VDCW	MAL GEM-612-.02
C 708	Capacitor, Fixed, Dur-Mica 43 MMFD, 500 VDCW	EM DM-15-43
C 709	Capacitor, Fixed, Disc .01 MFD, 600 VDCW	C DD6-103-.01
C 710	Capacitor, Fixed, Metallized Paper .1 MFD, 400 VDCW	AEO P 123ZG-.1
C 711	Capacitor, Fixed, Electrolytic 300 MFD, 3 VDCW	SP TE-1066-300
CR 101	Diode, Zener, Silicon IN Z102, Min. Breakdown Voltage 5.9 V	HO IN 429
CR 220	Diode, Crystal, General Purpose PIV 84 V	SYL IN 48
CR 221	Diode, Crystal, General Purpose PIV 84 V	SYL IN 48
CR 230	Rectifier, Silicon, 425 MA IN 1109, Max. PIV 1200 V	ST 120 SM
CR 231	Rectifier, Silicon, 425 MA IN 1109, Max. PIV 1200 V	ST 120 SM

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. & Mfr. Designation
CR 232	Rectifier, Silicon, 425 MA IN 1109, Max. PIV 1200 V	ST 120 SM
CR 233	Rectifier, Silicon, 425 MA IN 1109, Max. PIV 1200 V	ST 120 SM
CR 234	Rectifier, Silicon, 425 MA IN 1109, Max. PIV 1200 V	ST 120 SM
CR 239	Rectifier, Germanium, Double 400 MA, Max. PIV 380 V	GE IN 1016
CR 240	Rectifier, Germanium, Double 400 MA, Max. PIV 380 V	GE IN 1016
CR 301	Diode, Silicon PIV, 125 V, 4 MA	HO or HU IN 628
CR 302	Diode, Silicon PIV, 125 V, 4 MA	HO or HU IN 628
CR 303	Diode, Silicon PIV, 125 V, 4 MA	HO or HU IN 628
DS 202	Lamp, Neon, Indicating 65-130 VAC, 90-130 VDC	DR Type 105
DS 203	Lamp, Neon, Indicating 65-130 VAC, 90-130 VDC	DR Type 105
DS 204	Lamp, Neon, Indicating 65-130 VAC, 90-130 VDC	DR Type 105
DS 205	Lamp, Neon, Miniature, Indicating Clear Lens with 100 K Resistor	ELD Type IEG3
DS 206	Lamp, Neon, Miniature, Indicating Clear Lens with 100 K Resistor	ELD Type IEG3
F 201	Fuse, Slo-Blo 3 AG, 2 Amp	LF 313002
F 202	Fuse, Slo-Blo 3 AG, 4 Amp	LF 313004
[illegible]	Chopper	J C 2342
[illegible]	Relay, Medium Power 8 Amp, 115 V, DPDT	GU IR-1200-G 1 5
[illegible]	Choke, 3.5 Henry	[illegible]

Circuit Ref.	Description	Mfr. & Mfr. Designation
L 301	Choke, RF 750 UH, 250 MA	MIL 34300-750
L 302	Choke, 13 Turns #28 Wire Wound on R327	
L 303	Choke, 13 Turns #28 Wire Wound on R328	
L 401	Choke, Audio 720 Ω DC	HIL 71018
L 402	Choke, Audio 5500 Ω	HIL P 3751
L 403	Choke, Audio 2375 Ω	HIL 7812
L 404	Choke, Audio 2430 Ω	HIL 7813
L 405	Choke, Audio 720 Ω	HIL 71018
M 203	Meter 0-100 MA	GE HIL-513X10
P 201	Line Cord 3 Conductor	COR 3532
R 101	Resistor, Fixed, Composition 100 K Ω, 1/2 W, ± 10%	OHM RC-20-100K
R 102	Resistor, Fixed, Composition 100 K Ω, 1/2 W, ± 10%	OHM RC-20-100K
R 103	Resistor, Fixed, Wire Wound 2667 Ω, ± .05%	HIL 286-2667
R 104	Resistor, Variable, Wire Wound 200 Ω, ± 5%	DP 301-60-200
R 105	Resistor, Fixed, Wire Wound 3333 Ω, ± .05%	HIL 286-3333
R 106	Resistor, Fixed, Wire Wound 15 K Ω, 5 W, ± 1%	SA SS-5W-15K
R 107	Resistor, Fixed, Composition 1 Meg Ω, 1/2 W, ± 10%	OHM RC-20-1 MEG

Circuit Ref.	Description	Mfr. & Mfr. Designation
R 109	Resistor, Fixed, Composition 470 K Ω, 1/2 Watt, ± 10%	OHM RC-20-470K
R 110	Resistor, Fixed, Composition 22 K Ω, 1/2 Watt, ± 10%	OHM RC-20-22K
R 111	Resistor, Fixed, Composition 1 Meg Ω, 1/2 Watt, ± 10%	OHM RC-20-1 MEG
R 112	Resistor, Fixed, Composition 470 K Ω, 1/2 Watt, ± 10%	OHM RC-20-470K
R 113	Resistor, Fixed, Composition 22 K Ω, 1/2 Watt, ± 10%	OHM RC-20-22K
R 114	Resistor, Fixed, Composition 235 K Ω (2 each 470K Ω in parallel), 1/2 Watt, ±10%	OHM RC-20-235K(2
R 115	Resistor, Fixed, Composition 470 K Ω, 1/2 Watt, ± 10%	OHM RC-20-470K
R 116	Resistor, Fixed, Composition 470 K Ω, 1/2 Watt, ± 10%	OHM RC-20-470K
R 118	Resistor, Variable, Composition 1 Meg Ω, 2 Watt, ± 10%	OHM CLU 1052-1 ME
R 119	Resistor, Fixed, Composition 22 K Ω, 1 Watt, ± 10%	OHM RC-32-22K
R 120	Resistor, Fixed, Composition 3.9 K Ω, 1/2 Watt, ± 10%	OHM RC-20-3.9K
R 121	Resistor, Fixed, Composition 470 K Ω, 1/2 Watt, ± 10%	OHM RC-20-470K
R 122	Resistor, Fixed, Composition 470 K Ω, 1/2 Watt, ± 10%	OHM RC-20-470K
R 123	Resistor, Fixed, Composition 68 K Ω, 1/2 Watt, ± 10%	OHM RC-20-68K
R 124	Resistor, Fixed, Composition 470 K Ω, 1/2 Watt, ± 10%	OHM RC-20-470K
R 125	Resistor, Fixed, Composition 470 K Ω, 1/2 Watt, ± 10%	OHM RC-20-470K
R 126	Resistor, Fixed, Composition 220 Ω, 2 Watt, ± 10%	OHM RC-42-220

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. & Mfr. Designation
R 127	Resistor, Fixed, Composition 3.3K Ω, 1/2 Watt, ± 10%	OHM RC-20-3.3K
R 128	Resistor, Fixed, Composition Factory selected value	OHM RC-20
R 129	Resistor, Fixed, Composition 2.2 K Ω, 1/2 Watt, ± 10%	OHM RC-20-2.2K
R 201	Resistor, Fixed, Wire Wound 400 Ω, 20 Watt, ± 10%	OHM Brown Devil-400
R 202	Resistor, Fixed, Wire Wound 400 Ω, 20 Watt, ± 10%	OHM Brown Devil-400
R 203	Resistor, Fixed, Wire Wound 50 K Ω, 10 Watt, ± 10%	OHM Brown Devil-50K
R 204	Resistor, Fixed, Wire Wound 30 K Ω, 10 Watt, ± 10%	OHM Brown Devil-30K
R 205	Resistor, Fixed, Composition 100 K Ω, 1/2 Watt, ± 10%	OHM RC-20-100K
R 206	Resistor, Fixed, Composition 10 K Ω, 2 Watt, ± 10%	OHM RC-42-10K
R 207	Resistor, Fixed, Wire Wound 18 K Ω, 10 Watt, ± 10%	OHM Brown Devil-18K
R 208	Resistor, Fixed, Composition 33 K Ω, 1/2 Watt, ± 10%	OHM RC-20-33K
R 209	Resistor, Fixed, Composition 1 K Ω, 1/2 Watt, ± 10%	OHM RC-20-1K
R 210	Resistor, Fixed, Composition 1 K Ω, 1/2 Watt, ± 10%	OHM RC-20-1K
R 211	Resistor, Fixed, Composition 100 Ω, 1/2 Watt, ± 10%	OHM RC-20-100
R 212	Resistor, Fixed, Composition 100 Ω, 1/2 Watt, ± 10%	OHM RC-20-100
R 213	Resistor, Fixed, Composition 1 Meg Ω, 1/2 Watt, ± 10%	OHM RC-20-1 MEG
R 214	Resistor, Fixed, Composition 10 K Ω, 1/2 Watt, ± 10%	OHM RC-20-10K
R 215	Resistor, Fixed, Composition 1 Meg Ω, 1/2 Watt, ± 10%	OHM RC-20-1 MEG

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. & Mfr. Designation
R 216	Resistor, Fixed, Composition 10 K Ω, 1/2 Watt, ± 10%	OHM RC-20-10K
R 217	Resistor, Fixed, Composition 47 K Ω, 1/2 Watt, ± 10%	OHM RC-20-47K
R 218	Resistor, Fixed, Composition 1 Meg Ω, 1/2 Watt, ± 10%	OHM RC-20-1 MEG
R 219	Resistor, Fixed, Composition 100 K Ω, 1/2 Watt, ± 10%	OHM RC-20-100K
R 220	Resistor, Fixed, Composition 1 Meg Ω, 1/2 Watt, ± 10%	OHM RC-20-1 MEG
R 221	Resistor, Fixed, Composition 180 K Ω, 1/2 Watt, ± 10%	OHM RC-20-180K
R 222	Resistor, Fixed, Deposited Carbon 130 K Ω, 1/2 Watt, ± 1%	IRC DCC RN20X-130K
R 223	Resistor, Fixed, Composition 82 K Ω, 1/2 Watt, ± 10%	OHM RC-20-82K
R 224	Resistor, Fixed, Deposited Carbon 100 K Ω, 1/2 Watt, ± 1%	IRC DCC RN20X-100K
R 225	Resistor, Fixed, Composition 33 K Ω, 1 Watt, ± 10%	OHM RC-32-33K
R 226	Resistor, Fixed, Composition 330 K Ω, 1/2 Watt, ± 10%	OHM RC-20-330K
R 228	Resistor, Fixed, Composition 100 Ω, 1/2 Watt, ± 10%	OHM RC-20-100
R 229	Resistor, Fixed, Composition 100 Ω, 1/2 Watt, ± 10%	OHM RC-20-100
R 230	Resistor, Fixed, Composition 1 Meg Ω, 1/2 Watt, ± 10%	OHM RC-20-1 MEG
R 231	Resistor, Fixed, Composition 10 K Ω, 1/2 Watt, ± 10%	OHM RC-20-10K
R 232	Resistor, Fixed, Composition 1 Meg Ω, 1/2 Watt, ± 10%	OHM RC-20-1MEG
R 233	Resistor, Fixed, Composition 10 K Ω, 1/2 Watt, ± 10%	OHM RC-20-10K
R 234	Resistor, Fixed, Composition 47 K Ω, 1/2 Watt, ± 10%	OHM RC-20-47K

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. & Mfr. Designation
R 235	Resistor, Fixed, Composition 1 Meg Ω, 1/2 Watt, ± 10%	OHM RC-20-1 MEG
R 236	Resistor, Fixed, Composition 100 K Ω, 1/2 Watt, ± 10%	OHM RC-20-100K
R 237	Resistor, Fixed, Composition 1 Meg Ω, 1/2 Watt, ± 10%	OHM RC-20-1 MEG
R 238	Resistor, Fixed, Composition 180 K Ω, 1/2 Watt, ± 10%	OHM RC-20-180K
R 239	Resistor, Fixed, Deposited Carbon 75 K Ω, 1/2 Watt, ± 1%	IRC DCC RN20X-75K
R 240	Resistor, Fixed, Composition 82 K Ω, 1/2 Watt, ± 10%	OHM RC-20-82K
R 241	Resistor Fixed, Deposited Carbon 100 K Ω, 1/2 Watt, ± 1%	IRC DCC RN20X-100K
R 242	Resistor, Fixed, Composition 470 K Ω, 1/2 Watt, ± 10%	OHM RC-20-470K
R 245	Resistor, Fixed, Wire Wound 75 Ω, 25 Watt, ± 10%	OHM Brown Devil-75
R 246	Resistor, Fixed, Wire Wound 100 Ω, 20 Watt, ± 10%	OHM Brown Devil-100
R 247	Resistor, Fixed, Wire Wound 1.5 K Ω, 25 Watt, ± 10%	OHM Brown Devil-1.5
R 249	Resistor, Fixed, Composition 100 K Ω, 1 Watt, ± 10%	OHM RC-32-100K
R 250	Resistor, Fixed, Composition 390 K Ω, 1 Watt, ± 10%	OHM RC-32-390K
R 260	Resistor, Fixed, Composition 2200 Ω, 1/2 Watt, ± 10%	OHM RC-20-2.2K
R 261	Resistor, Fixed, Composition 2200 Ω, 1/2 Watt, ± 10%	OHM RC-20-2.2K
R 262	Resistor, Variable, Dual, Composition 25 K Ω/25 K Ω, 2 Watt, ± 10%	OHM CCU 2531-25
R 263	Resistor, Fixed, Composition 33 K Ω, 1/2 Watt, ± 10%	OHM RC-20-33K
R 264	Resistor, Fixed, Deposited Carbon 470 K Ω, 1/2 Watt, ± 1%	IRC DCC RN20X-470K

Circuit Ref.	Description	Mfr. & Mfr. Designation
R 265	Resistor, Fixed, Deposited Carbon 470 K Ω, 1/2 Watt, ± 1%	IRC DCC RN20X-470K
R 266	Resistor, Fixed, Composition 33 K Ω, 1/2 Watt, ± 10%	OHM RC-20-33K
R 267	Resistor, Variable, Composition 500 Ω, 2 Watt, ± 10%	OHM CLU 5011-500
R 268	Resistor, Fixed, Composition 100 K Ω, 1/2 Watt, ± 10%	OHM RC-20-100K
R 269	Resistor, Fixed, Composition 1200 Ω, 1/2 Watt, ± 10%	OHM RC-20-1.2K
R 270	Resistor, Fixed, Composition 1500 Ω, 1/2 Watt, ± 10%	OHM RC-20-1.5K
R 271	Resistor, Variable, Composition 1000 Ω, 2 Watt, ± 10%	OHM CLU 1021-1K
R 272	Resistor, Fixed, Composition 1200 Ω, 1/2 Watt, ± 10%	OHM RC-20-1.2K
R 273	Resistor, Fixed, Composition 1 Meg Ω, 1/2 Watt, ± 10%	OHM RC-20-1 MEG
R 274	Resistor, Fixed, Composition 1 K Ω, 1/2 Watt, ± 10%	OHM RC-20-1K
R 275	Resistor, Fixed, Composition 100 Ω, 1/2 Watt, ± 10%	OHM RC-20-100
R 276	Resistor, Fixed, Composition 100 Ω, 1/2 Watt, ± 10%	OHM RC-20-100
R 277	Resistor, Fixed, Composition 1000 Ω, 1/2 Watt, ± 10%	OHM RC-20-1K
R 278	Resistor, Fixed, Composition 27 K Ω, 1/2 Watt, ± 10%	OHM RC-20-27K
R 279	Resistor, Fixed, Deposited Carbon 1200 Ω, 1/2 Watt, ± 1%	IRC DCC RN20X-1.2K
R 280	Resistor, Variable, Dual, Wire Wound 1 K Ω/10 K Ω, ± 3%	HIL 5-850-1K-10K
R 281	Resistor, Fixed, Composition 270 K Ω, 1/2 Watt, ± 10%	OHM RC-20-270K
R 282	Resistor, Fixed, Composition 330 Ω, 1/2 Watt, ± 10%	OHM RC-20-330

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. & Mfr. Designation
R 283	Resistor, Fixed, Composition 820 Ω, 1/2 Watt, ± 10%	OHM RC-20-820
R 284	Resistor, Fixed, Composition 1000 Ω, 1/2 Watt, ± 10%	OHM RC-20-1K
R 285	Resistor, Fixed, Composition 1000 Ω, 1/2 Watt, ± 10%	OHM RC-20-1K
R 286	Resistor, Fixed, Composition 220 K Ω, 1/2 Watt, ± 10%	OHM RC-20-220K
R 287	Resistor, Fixed, Composition 39 K Ω, 1/2 Watt, ± 10%	OHM RC-20-39K
R 288	Resistor, Fixed, Composition 68 K Ω, 1 Watt, ± 10%	OHM RC-32-68K
R 289	Resistor, Fixed, Composition Value selected at factory	OHM RC-20
R 290	Resistor, Fixed, Composition 3 Ω, 5 Watt, ± 10%	OHM Brown Devil-3
R 301	Resistor, Fixed, Wire Wound 10 K Ω, ± .05%, Mica Card	HIL 602-305-2-10K
R 302	Resistor, Fixed, Wire Wound 10 K Ω, ± .05%, Mica Card	HIL 602-305-2-10K
R 303	Resistor, Fixed, Composition 6.8 K Ω, 2 Watt, ± 10%	OHM RC-42-6.8K
R 304	Resistor, Fixed, Composition 1.8 K Ω, 1/2 Watt, ± 10%	OHM RC-20-1.8K
R 305	Resistor, Fixed, Composition 680 Ω, 1/2 Watt, ± 10%	OHM RC-20-680
R 306	Resistor, Fixed, Deposited Carbon 1 Meg Ω, 1/2 Watt, ± 1%	IRC DCC RN20X-1 MEG
R 307	Resistor, Fixed, Deposited Carbon Value factory selected, 1/2 Watt, ± 1%	IRC DCC RN20X
R 308	Resistor, Fixed, Deposited Carbon 4.3 Meg Ω, 1/2 Watt, ± 1%	IRC DCC RN20X-4.3 M
R 309	Resistor, Fixed, Composition 6.8 K Ω, 2 Watt, ± 10%	OHM RC-42-6.8K
R 310	Resistor, Fixed, Composition 1.8K Ω, 1/2 Watt, ± 10%	OHM RC-20-1.8K

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. & Mfr. Designation
R 311	Resistor, Fixed, Composition 820 Ω, 1/2 Watt, ± 10%	OHM RC-20-820
R 312	Resistor, Fixed, Composition 3.9 Meg Ω, 1/2 Watt, ± 10%	OHM RC-20-3.9 MEG
R 313	Resistor, Fixed, Composition 1 Meg Ω, 1/2 Watt, ± 10%	OHM RC-20-1 MEG
R 314	Resistor, Fixed, Deposited Carbon 1 Meg Ω, 1/2 Watt, ± 1%	IRC DCC RN20X-1 MEG
R 315	Resistor, Fixed, Composition 1.2 K Ω, 1/2 Watt, ± 10%	OHM RC-20-1.2K
R 316	Resistor, Fixed, Deposited Carbon 4.7 Meg Ω, 1/2 Watt, ± 1%	IRC DCC RN20X-4.7 ME
R 318	Resistor, Fixed, Wire Wound 10 K Ω, 10 Watt, ± 10%	OHM Brown Devil-10K
R 319	Resistor, Fixed, Deposited Carbon 130 K Ω, 1/2 Watt, ± 1%	IRC DCC RN20X-130K
R 320	Resistor, Fixed, Wire Wound 10 K Ω, ± .05%, Mica Card	HIL 602-305-2-10K
R 321	Resistor, Fixed, Wire Wound 10 K Ω, ± .05%, Mica Card	HIL 602-305-2-10K
R 322	Resistor, Fixed, Wire Wound 435 Ω, ± .05%, Jelly Bean	HIL 286-435
R 323	Resistor, Fixed, Deposited Carbon Value varies with unit, 1/2 Watt, ± 1%	IRC DCC RN20X
R 324	Resistor, Fixed, Wire Wound 305.0 Ω, ± .05%, Mica Card	HIL 602-305
R 325	Resistor, Variable, Wire Wound 10 Ω, ± 5%	DP 301-60-10

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. & Mfr. Designation
R 326	Resistor, Variable, Composition 100 Ω, 2 Watt, ± 10%	OHM CLU 1011-100
R 327	Resistor, Fixed, Composition 150 Ω, 1/2 Watt, ± 10%	OHM RC-20-150
R 328	Resistor, Fixed, Composition 150 Ω, 1/2 Watt, ± 10%	OHM RC-20-150
R 329	Resistor, Fixed, Wire Wound 10 Ω, 1/2 Watt, ± .05% Jelly Bean	HIL 286-10
R 330	Resistor, Fixed, Metal Film 5 Ω, ± 1%, 1/2 Watt	DA 850-5
R 331	Resistor, Fixed, Composition 470 K, 1/2 Watt, ± 10%	OHM RC20-470K
R 401	Resistor, Fixed, Wire Wound 100 K Ω, ± .05%, Round Bobbin	HIL 185-100K
R 402	Resistor, Fixed, Wire Wound 50 K Ω, ± .05%, Round Bobbin	HIL 185-50K

Circuit Ref.	Description	Mfr. & Mfr. Designation
R 601	Resistor, Fixed, Wire Wound 30K Ω, ± .05%, Mica-Card	HIL 602-30K
R 602	Resistor, Fixed, Wire Wound 30K Ω, ± .05%, Mica-Card	HIL 602-30K
R 603	Resistor, Fixed, Wire Wound 30K Ω, ± .05%, Mica-Card	HIL 602-30K
R 604	Resistor, Fixed, Wire Wound 30K Ω, ± .05%, Mica-Card	HIL 602-30K
R 605	Resistor, Fixed, Wire Wound 30K Ω, ± .05%, Mica-Card	HIL 602-30K
R 606	Resistor, Fixed, Wire Wound 30K Ω, ± .05%, Mica-Card	HIL 602-30K
R 607	Resistor, Fixed, Wire Wound 30K Ω, ± .05%, Mica-Card	HIL 602-30K
R 608	Resistor, Fixed, Wire Wound 30K Ω, ± .05%, Mica-Card	HIL 602-30K
R 609	Resistor, Fixed, Wire Wound 29.7K Ω, ± .05%, Mica-Card	HIL 510-390-29.7K
R 611	Resistor, Fixed, Wire Wound 3K Ω, ± .05%, Mica-Card	HIL 602-305-2-3K
R 612	Resistor, Fixed, Wire Wound 3K Ω, ± .05%, Mica-Card	HIL 602-305-2-3K
R 613	Resistor, Fixed, Wire Wound 3K Ω, ± .05%, Mica-Card	HIL 602-305-2-3K
R 614	Resistor, Fixed, Wire Wound 3K Ohms, ± .05%, Mica-Card	HIL 602-305-2-3K
R 615	Resistor, Fixed, Wire Wound 3K Ω, ± .05%, Mica-Card	HIL 602-305-2-3K
R 616	Resistor, Fixed, Wire Wound 3K Ω, ± .05%, Mica-Card	HIL 602-305-2-3K
R 617	Resistor, Fixed, Wire Wound 3K Ω, ± .05%, Mica-Card	HIL 602-305-2-3K
R 618	Resistor, Fixed, Wire Wound 3K Ω, ± .05%, Mica-Card	HIL 602-305-2-3K

Circuit Ref.	Description	Mfr. & Mfr. Designation
R 619	Resistor, Fixed, Wire Wound 2.7K Ω, ± .05%, Mica-Card	HIL 510-390-2.7K
R 624	Resistor, Fixed, Wire Wound 300 Ω, ± .05%, Mica-Card	HIL 602-300
R 625	Resistor, Fixed, Wire Wound 300 Ω, ± .05%, Mica-Card	HIL 602-300
R 626	Resistor, Fixed, Wire Wound 300 Ω, ± .05%, Mica-Card	HIL 602-300
R 627	Resistor, Fixed, Wire Wound 300 Ω, ± .05%, Mica-Card	HIL 602-300
R 628	Resistor, Fixed, Wire Wound 300 Ω, ± .05%, Mica-Card	HIL 602-300
R 629	Resistor, Fixed, Wire Wound 300 Ω, ± .05%, Mica-Card	HIL 602-300
R 630	Resistor, Fixed, Wire Wound 300 Ω, ± .05%, Mica-Card	HIL 602-300
R 631	Resistor, Fixed, Wire Wound 300 Ω, ± .05%, Mica-Card	HIL 602-300
R 632	Resistor, Fixed, Wire Wound 300 Ω, ± .05%, Mica-Card	HIL 602-300
R 633	Resistor, Fixed, Wire Wound 300 Ω, ± .05%, Mica-Card	HIL 602-300
R 635	Resistor, Fixed, Wire Wound 30 Ω, ± .05%, Mica Card	HIL 286-30
R 636	Resistor, Fixed, Wire Wound 30 Ω, ± .05%, Mica-Card	HIL 286-30
R 637	Resistor, Fixed, Wire Wound 30 Ω, ± .05%, Mica-Card	HIL 286-30
R 638	Resistor, Fixed, Wire Wound 30 Ω, ± .05%, Mica-Card	HIL 286-30
R 639	Resistor, Fixed, Wire Wound 30 Ω, ± .05%, Mica-Card	HIL 286-30
R 640	Resistor, Fixed, Wire Wound 30 Ω, ± .05%, Mica Card	HIL 286-30

Circuit Ref.	Description	Mfr. & Mfr. Designation
R 641	Resistor, Fixed, Wire Wound 30 Ω, ± .05%, Mica-Card	HIL 286-30
R 642	Resistor, Fixed, Wire Wound 30 Ω, ± .05%, Mica-Card	HIL 286-30
R 643	Resistor, Fixed, Wire Wound 30 Ω, ± .05%, Mica-Card	HIL 286-30
R 644	Resistor, Variable, Wire Wound 30 Ω, ± 1%	HIL 130-30
R 655	Resistor, Fixed, Wire Wound 2250 Ω, 25 Watt, ± 10%	OHM 03773-2250
R 656	Resistor, Fixed, Wire Wound 2250 Ω, 25 Watt, ± 10%	OHM 03773-2250
R 657	Resistor, Fixed, Wire Wound 350 Ω, 5 Watt, ± 10%	OHM Brown Devil-350
R 658	Resistor, Fixed, Wire Wound 400 Ω, 5 Watt, ± 10%	OHM Brown Devil-400
R 659	Resistor, Fixed, Wire Wound 500 Ω, 5 Watt, ± 10%	OHM Brown Devil-500
R 660	Resistor, Fixed, Wire Wound 750 Ω, 5 Watt, ± 10%	OHM Brown Devil-750
R 661	Resistor, Fixed, Wire Wound 1K Ω, 5 Watt, ± 10%	OHM Brown Devil-1K
R 662	Resistor, Fixed, Wire Wound 1.5K Ω, 5 Watt, ± 10%	OHM Brown Devil-1.5K
R 663	Resistor, Fixed, Wire Wound 2.5K Ω, 5 Watt, ± 10%	OHM Brown Devil-2.5K
R 664	Resistor, Fixed, Wire Wound 5K Ω, 5 Watt, ± 10%	OHM Brown Devil-5K
R 665	Resistor, Fixed, Wire Wound 15K Ω, 5 Watt, ± 10%	OHM Brown Devil-15K
R 666	Resistor, Fixed, Deposited Carbon 30K Ω, 1/2 Watt, ± 1%	IRC DCC RN20X-30K
R 667	Resistor, Fixed, Deposited Carbon 47K Ω, 1/2 Watt, ± 1%	IRC DCC RN20X-47K

Circuit Ref.	Description	Mfr. & Mfr. Designation
R 668	Resistor, Fixed, Deposited Carbon 22 K Ω, 1/2 Watt, ± 1%	IRC DCC-RN20X-22K
R 669	Resistor, Fixed, Composition 4.7K Ω, 1/2 Watt, ± 10%	OHM RC-20-4.7K
R 670	Resistor, Fixed, Composition 4.7 K Ω, 1/2 Watt, ± 10%	OHM RC-20-4.7K
R 671	Resistor, Fixed, Composition 10 K Ω, 1/2 Watt, ± 10%	OHM RC-20-10K
R 672	Resistor, Fixed, Composition 10 K Ω, 1/2 Watt, ± 10%	OHM RC-20-10K
R 673	Resistor, Fixed, Composition 10 K Ω, 1/2 Watt, ± 10%	OHM RC-20-10K
R 674	Resistor, Fixed, Composition 39 K Ω, 1/2 Watt, ± 10%	OHM RC-20-39K
R 675	Resistor, Fixed, Composition 39 K Ω, 1/2 Watt, ± 10%	OHM RC-20-39K
R 676	Resistor, Fixed, Composition 100 K Ω, 1/2 Watt, ± 10%	OHM RC-20-100K
R 677	Resistor, Fixed, Composition 18 K Ω, 1/2 Watt, ± 10%	OHM RC-20-18K
R 678	Resistor, Fixed, Composition 18 K Ω, 1/2 Watt, ± 10%	OHM RC-20-18K
R 679	Resistor, Fixed, Composition 18 K Ω, 1/2 Watt, ± 10%	OHM RC-20-18K
R 680	Resistor, Fixed, Composition 18 K Ω, 1/2 Watt, ± 10%	OHM RC-20-18K
R 681	Resistor, Fixed, Composition 18 K Ω, 1/2 Watt, ± 10%	OHM RC-20-18K
R 702	Resistor, Fixed, Composition 100 K Ω, 1/2 Watt, ± 10%	OHM RC-20-100K
R 704	Resistor, Fixed, Composition 10 K Ω, 1/2 Watt, ± 10%	OHM RC-20-10K
R 705	Resistor, Fixed, Deposited Carbon 150 Ω, 1/2 Watt, ± 1%	IRC DCC-RN20X-150

Circuit Ref.	Description	Mfr. & Mfr. Designation
R 706	Resistor, Fixed, Composition 39 K Ω, 1/2 Watt, ± 10%	OHM RC-20-39K
R 707	Resistor, Fixed, Composition 2.2 Meg Ω, 1/2 Watt, ± 10%	OHM RC-20-2.2 MEG
R 708	Resistor, Fixed, Composition 27 K Ω, 1/2 Watt, ± 10%	OHM RC-20-27K
R 709	Resistor, Variable, Composition 10 K Ω, 2 Watt, ± 10%	OHM CLU 1031-10K
R 710	Resistor, Fixed, Composition 22 K Ω, 1/2 Watt, ± 10%	OHM RC-20-22K
R 712	Resistor, Fixed, Composition 47 K Ω, 1 Watt, ± 10%	OHM RC-20-47K
R 713	Resistor, Fixed, Composition 1 Meg Ω, 1/2 Watt, ± 10%	OHM RC-20-1 MEG
R 714	Resistor, Fixed, Composition 3.9 K Ω, 1/2 Watt, ± 10%	OHM RC-20-3.9K
R 715	Resistor, Fixed, Composition 1 Meg Ω, 1/2 Watt, ± 10%	OHM RC-20-1 MEG
R 716	Resistor, Fixed, Composition 47 K Ω, 1 Watt, ± 10%	OHM RC-32-47K
R 717	Resistor, Fixed, Composition 22 K Ω, 1/2 Watt, ± 10%	OHM RC-20-22K
R 718	Resistor, Fixed, Composition 1 Meg Ω, 1/2 Watt, ± 10%	OHM RC-20-1 MEG
R 719	Resistor, Fixed, Composition 100 K Ω, 2 Watt, ± 10%	OHM RC-42-100K
R 720	Resistor, Fixed, Composition 1 Meg Ω, 1/2 Watt, ± 10%	OHM RC-20-1 MEG
R 721	Resistor, Fixed, Composition 220 K Ω, 1/2 Watt, ± 10%	OHM RC-20-220K
R 722	Resistor, Fixed, Composition 220 K Ω, 1/2 Watt, ± 10%	OHM RC-20-220K
R 724	Resistor, Fixed, Composition 100 Ω, 1/2 Watt, ± 10%	OHM RC-20-100

TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. & Mfr. Designation
R 725	Resistor, Fixed, Composition 560 Ω, 2 Watt, ± 10%	OHM RC-42-560
R 726	Resistor, Fixed, Composition 100 Ω, 1/2 Watt, ± 10%	OHM RC-20-100
R 729	Resistor, Fixed, Composition 100 Ω, 1/2 Watt, ± 10%	OHM RC-20-100
R 730	Resistor, Fixed, Composition 560 Ω, 2 Watt, ± 10%	OHM RC-42-560
R 731	Resistor, Fixed, Composition 100 Ω, 1/2 Watt, ± 10%	OHM RC-20-100
R 733	Resistor, Fixed, Deposited Carbon 27 K Ω, 1/2 Watt, ± 1%	IRC DCC RN20X-27K
R 734	Resistor, Fixed, Composition 2.7 K Ω, 1/2 Watt, ± 10%	OHM RC-20-2.7K
R 735	Resistor, Fixed, Composition 470 K Ω, 1/2 Watt, ± 5%	OHM RC-20-470K
R 737	Resistor, Fixed, Composition 470 K Ω, 1/2 Watt, ± 5%	OHM RC-20-470K
R 738	Resistor, Fixed, Wire Wound 100 Ω, 10 Watt, ± 10%, Center Tap	OHM 1668-100
R 739	Resistor, Fixed, Wire Wound 100 Ω, 10 Watt, ± 10% Center Tap	OHM 1668-100
R 740	Resistor, Fixed, Composition 910 K Ω, 1/2 Watt, ± 5%	OHM RC-20-910K
RT 201	Lamp, Incandescant 230 V, 10 Watt	GE S-6
S 201	Relay, Time Delay 115 V	AMP 115N030
S 203	Switch, Bat Handle, Toggle SPST, 3 Amp, 250 V	AH&H 20994-LH
S 204	Switch, Bat Handle, Toggle DPDT, 3 Amp, 250 V	AH&H 81027-CE
S 205	Switch, Lever, Locking 120 V, 2 Amp	SC 300 GL

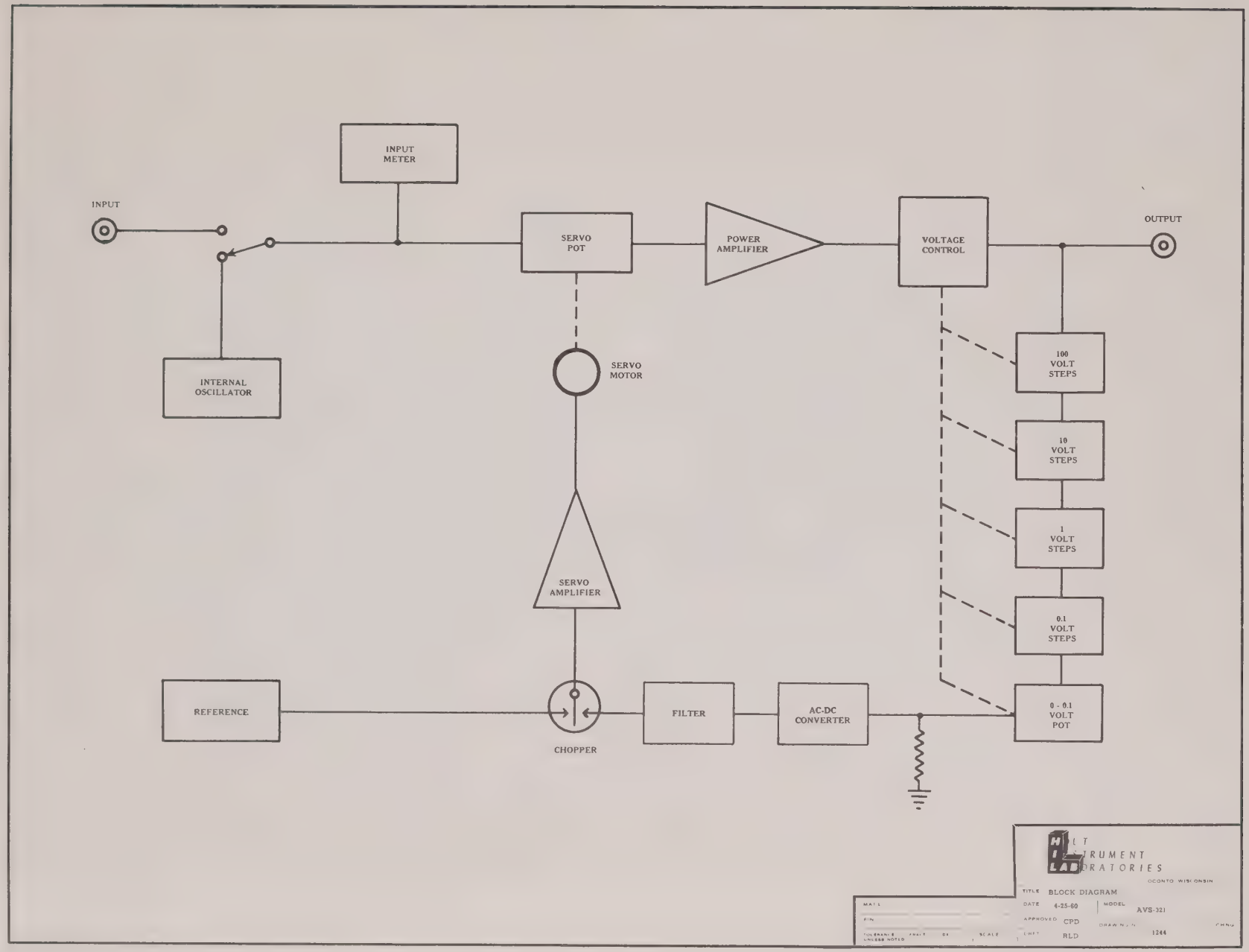
TABLE OF REPLACEABLE PARTS

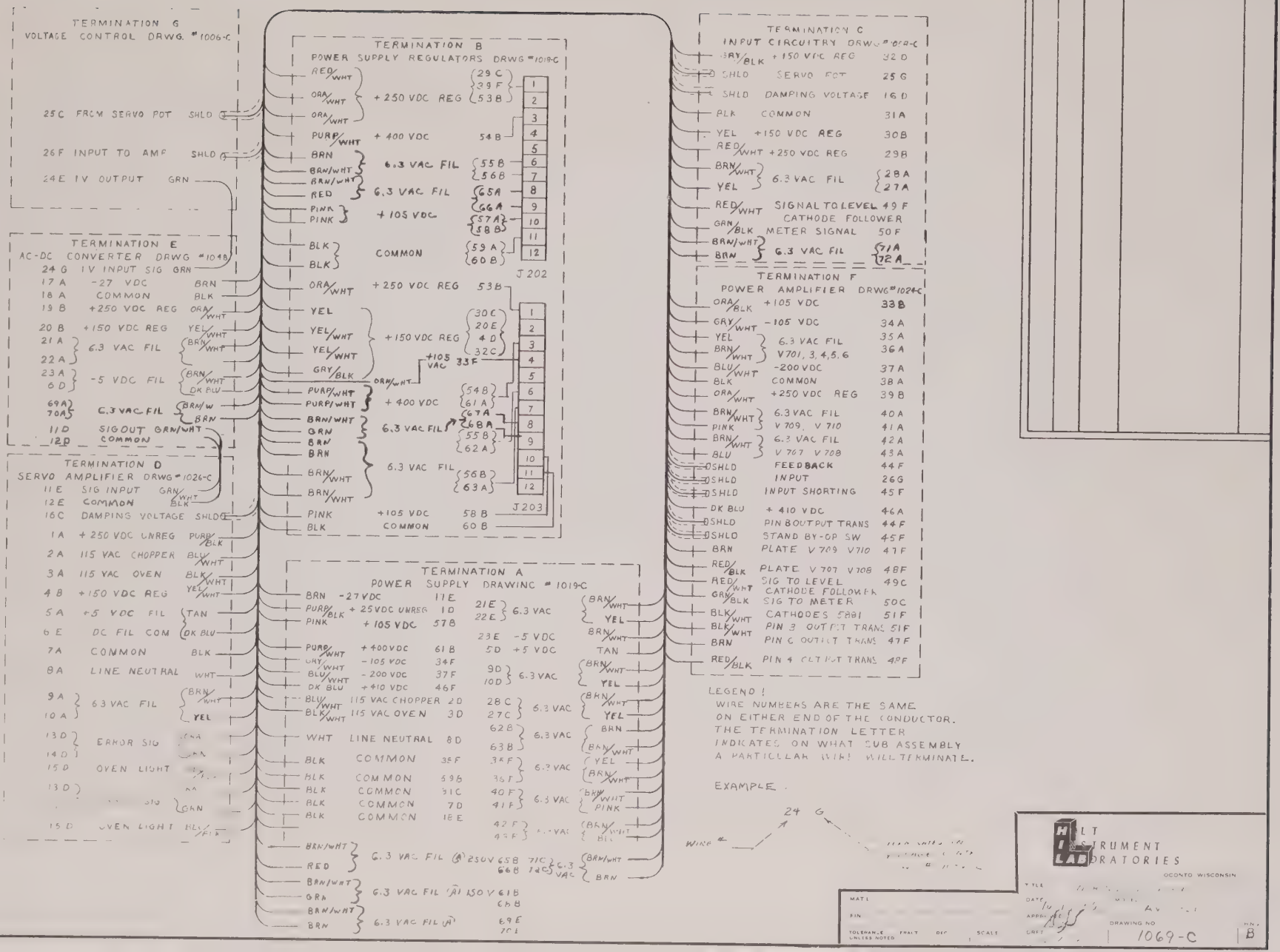
Circuit Ref.	Description	Mfr. & Mfr. Designation
S 600	Decade Switch Assembly 100 Volt Steps	HIL 600
S 601	Decade Switch Assembly 10 Volt Steps	HIL 601
S 602	Decade Switch Assembly 1 Volt Steps	HIL 602
S 603	Decade Switch Assembly 0.1 Volt Steps	HIL 603
S 604	Load Watts Switch	HIL 604
T 101	Transformer, Output	HIL P3750
T 204	Transformer, Plate	HIL P4200
T 205	Transformer, Filament	HIL P4201
T 601	Transformer, Hi-Voltage	HIL 80915
T 701	Transformer, Output .	HIL 81916
V 101	Tube, Electron	RCA 12AX7
V 102	Tube, Electron	RCA 12AX7
V 103	Tube, Electron	RCA 6AQ5
V 104	Tube, Electron	RCA 6AQ5
V 201	Tube, Electron	RCA 5Y3
V 202	Tube, Electron	RCA 5Y3
V 203	Tube, Electron	RCA 12AT7
V 205	Tube, Electron	RCA 12AT7

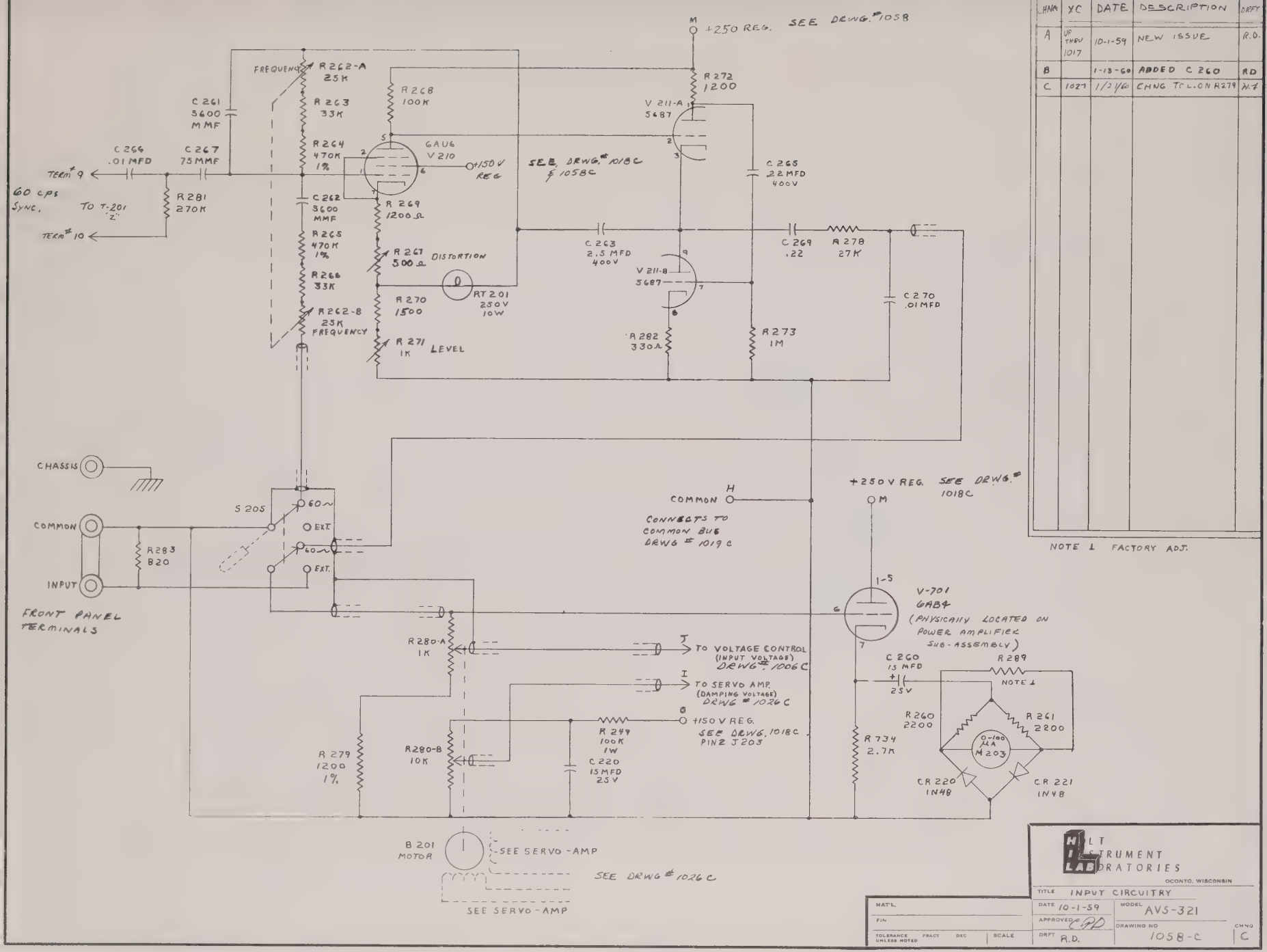
TABLE OF REPLACEABLE PARTS

Circuit Ref.	Description	Mfr. & Mfr. Designation
V 206	Tube, Electron	RCA 12AV7
V 208	Tube, Electron	RCA 12 AX7
V 209	Tube, Electron	RCA 12AV7
V 210	Tube, Electron	RCA 6AU6
V 211	Tube, Electron	RCA 5687
V 212	Tube, Electron	RCA 12AV7
V 213	Tube, Electron	RCA 12AV7
V 301	Tube, Electron	RCA 6136
V 302	Tube, Electron	RCA 6AU6
V 303	Tube, Electron	RCA 6AU6
V 304	Tube, Electron	RCA 5687
V 701	Tube, Electron	RCA 6AB4
V 702	Tube, Electron	RCA 0B2
V 703	Tube, Electron	RCA 12AX7
V 704	Tube, Electron	RCA 12AU7
V 705	Tube, Electron	RCA 12AU7
V 706	Tube, Electron	RCA 12AX7

Circuit Ref.	Designation	Mfr. & Mfr. Designation
V 707	Tube, Electron	RCA 5881
V 708	Tube, Electron	RCA 5881
V 709	Tube, Electron	RCA 5881
V 710	Tube, Electron	RCA 5881
Z 102	Oven Temp. 55°C., 117 VAC	NE 62


INPUT METER
INPUT
SERVO POT
POWER AMPLIFIER
VOLTAGE CONTROL
OUTPUT
INTERNAL OSCILLATOR
SERVO MOTOR
100 VOLT STEPS
10 VOLT STEPS
1 VOLT STEPS
0.1 VOLT STEPS
SERVO AMPLIFIER
REFERENCE
CHOPPER
FILTER
AC-DC CONVERTER
0 - 0.1 VOLT POT
TITLE BLOCK DIAGRAM
DATE 4-25-60
MODEL AVS-321
APPROVED CPD
RLD
1244


TERMINATION G
VOLTAGE CONTROL DRWG. # 1006-C
25C FROM SERVO POT SHLD
26F INPUT TO AMP SHLD
24E IV OUTPUT GRN
TERMINATION E
AC-DC CONVERTER DRWG # 1048
24 G IV INPUT SIG GRN
17 A -27 VDC BRN
18 A COMMON BLK
19 B +250 VDC REG ORA/WHT
20 B +150 VDC REG YEL/WHT
21 A 22 A 6.3 VAC FIL BRN/WHT
23 A 6 D -5 VDC FIL BRN/WHT DK BLU
69 A 70 A C.3 VAC FIL BRN/W BRN
11 D SIG OUT GRN/WHT
12 D COMMON
TERMINATION D
SERVO AMPLIFIER DRWG # 1026-C
11E SIG INPUT GRN/WHT
12E COMMON BLK
16C DAMPING VOLTAGE SHLD
1A +250 VDC UNREG PURP/BLK
2A 115 VAC CHOPPER BLU/WHT
3A 115 VAC OVEN BLK/WHT
4B +150 VDC REG YEL/WHT
5A +5 VDC FIL TAN
6E DC FIL COM DK BLU
7A COMMON BLK
8A LINE NEUTRAL WHT
9A 10A 6.3 VAC FIL BRN/WHT YEL
13D 14D ERROR SIG
15D OVEN LIGHT
13D SIG GRN
15D OVEN LIGHT BLU/WHT
TERMINATION B
POWER SUPPLY REGULATORS DRWG # 1019-C
RED/WHT ORA/WHT ORA/WHT +250 VDC REG 29C 39F 53B
PURP/WHT +400 VDC 54B
BRN BRN/WHT BRN/WHT RED 6.3 VAC FIL 55B 56B 6.3 VAC FIL 65A 66A
PINK PINK +105 VDC 57A 58B
BLK BLK COMMON 59A 60B
J202
ORA/WHT +250 VDC REG 53B
YEL YEL/WHT YEL/WHT GRY/BLK +150 VDC REG 30C 20E 4D 32C
+105 VAC 33F
ORA/WHT
PURP/WHT PURP/WHT +400 VDC 54B 61A
BRN/WHT GRN BRN BRN 6.3 VAC FIL 67A 68A 55B 62A
BRN/WHT BRN/WHT 6.3 VAC FIL 56B 63A
J203
PINK +105 VDC 58B
BLK COMMON 60B
TERMINATION A
POWER SUPPLY DRAWING # 1019-C
BRN -27 VDC 11E
PURP/BLK +25 VDC UNREG 1D
PINK +105 VDC 57B
21E 22E 6.3 VAC BRN/WHT YEL
23E -5 VDC BRN/WHT TAN
5D +5 VDC
PURP/WHT +400 VDC 61B
GRY/WHT -105 VDC 34F
BLU/WHT -200 VDC 37F
DK BLU +410 VDC 46F
9D 10D 6.3 VAC BRN/WHT YEL
BLU/WHT 115 VAC CHOPPER 2D
BLK/WHT 115 VAC OVEN 3D
28C 27C 6.3 VAC BRN/WHT YEL
WHT LINE NEUTRAL 8D
62B 63B 6.3 VAC BRN BRN/WHT
BLK COMMON 38F
BLK COMMON 59B
BLK COMMON 31C
BLK COMMON 7D
BLK COMMON 18E
3AF 36F 6.3 VAC YEL BRN/WHT
40F 41F 6.3 VAC BRN/WHT PINK
42F 43F 6.3 VAC BRN/WHT BLK
BRN/WHT RED 6.3 VAC FIL (A) 250V 65B 66B 71C 72C 6.3 VAC BRN/WHT BRN
BRN/WHT GRN BRN/WHT BRN 6.3 VAC FIL (A) 150V 61B 68B 6.3 VAC FIL (A) 69E 70E
TERMINATION C
INPUT CIRCUITRY DRWG # 1018-C
BRY/BLK +150 VDC REG 32D
SHLD SERVO POT 25G
SHLD DAMPING VOLTAGE 16D
BLK COMMON 31A
YEL +150 VDC REG 30B
RED/WHT +250 VDC REG 29B
BRN/WHT YEL 6.3 VAC FIL 28A 27A
RED/WHT SIGNAL TO LEVEL CATHODE FOLLOWER 49F
GRN/BLK METER SIGNAL 50F
BRN/WHT BRN 6.3 VAC FIL 71A 72A
TERMINATION F
POWER AMPLIFIER DRWG # 1024-C
ORA/BLK +105 VDC 33B
GRY/WHT -105 VDC 34A
YEL BRN/WHT 6.3 VAC FIL V701, 3, 4, 5, 6 35A 36A
BLU/WHT -200 VDC 37A
BLK COMMON 38A
ORA/WHT +250 VDC REG 39B
BRN/WHT 6.3 VAC FIL 40A
PINK V 709, V 710 41A
BRN/WHT 6.3 VAC FIL 42A
BLU V 707 V 708 43A
SHLD FEEDBACK 44F
SHLD INPUT 26G
SHLD INPUT SHORTING 45F
DK BLU +410 VDC 46A
SHLD PIN 8 OUTPUT TRANS 44F
SHLD STAND BY-OP SW 45F
BRN PLATE V 709 V710 47F
RED/BLK PLATE V 707 V 708 48F
RED/WHT SIG TO LEVEL CATHODE FOLLOWER 49C
GRN/BLK SIG TO METER 50C
BLK/WHT CATHODES 5881 51F
BLK/WHT PIN 3 OUTPUT TRANS 51F
BRN PIN 5 OUTPUT TRANS 47F
RED/BLK PIN 4 OUTPUT TRANS 48F
LEGEND!
WIRE NUMBERS ARE THE SAME ON EITHER END OF THE CONDUCTOR. THE TERMINATION LETTER INDICATES ON WHAT SUB ASSEMBLY A PARTICULAR WIRE WILL TERMINATE.
EXAMPLE.
24 G
WIRE #
A — 2-6-60 ADD R287 RD
B 1029 3-27-60 FIL CHANGE RD
HILT INSTRUMENT LABORATORIES
OCONTO WISCONSIN
TITLE
DRAWING NO 1069-C
B

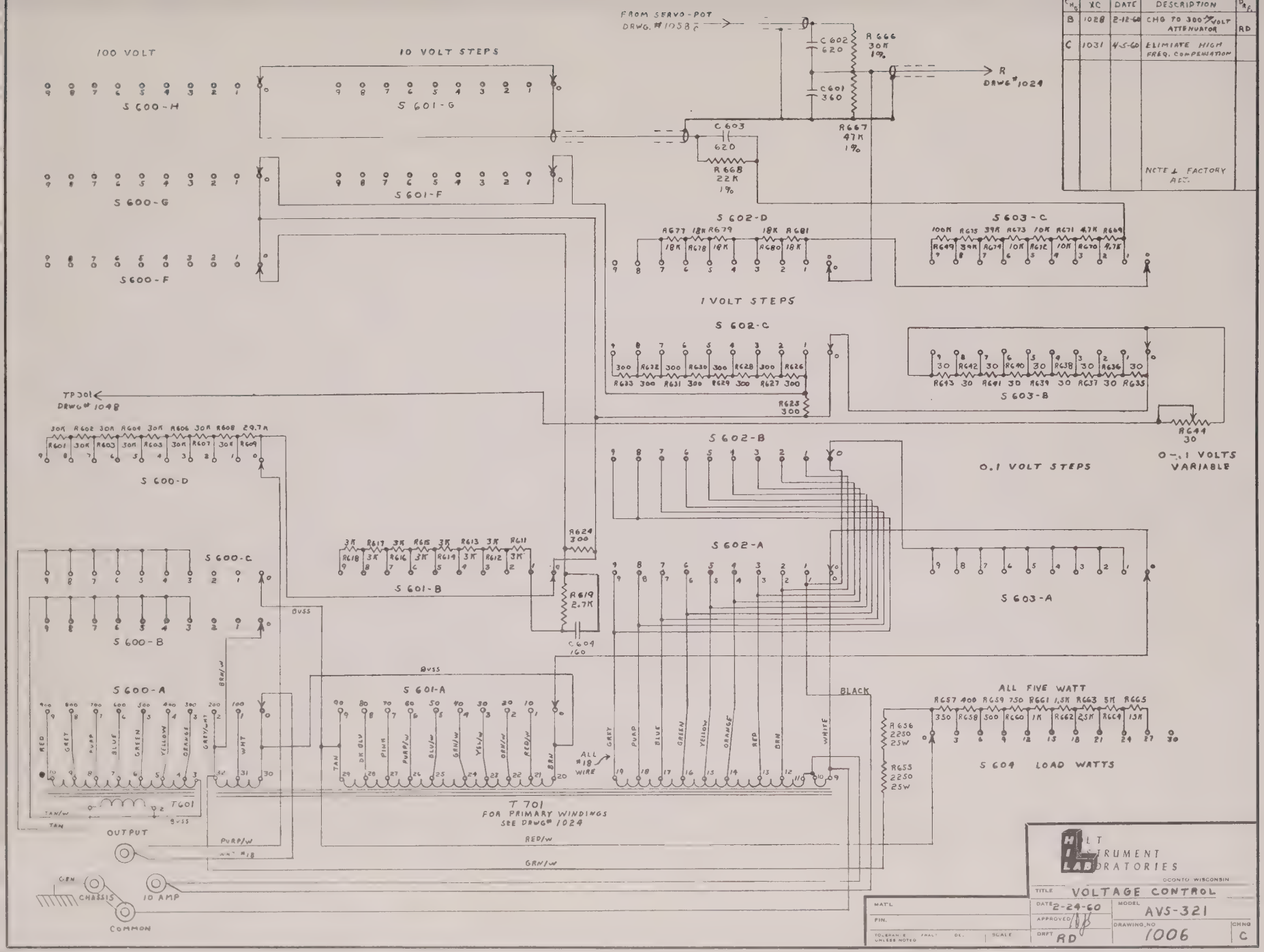


CHNG	XC	DATE	DESCRIPTION	DRFT
A	UP THRU 1017	10-1-59	NEW ISSUE	R.D.
B		1-13-60	ADDED C 260	RD
C	1027	1/21/60	CHNG TOL. ON R279	N.T

NOTE 1 FACTORY ADJ.

HI LAB INSTRUMENT LABORATORIES
OCONTO, WISCONSIN

TITLE	INPUT CIRCUITRY
MAT'L	
FIN	
TOLERANCE UNLESS NOTED FRACT DEC SCALE	
DATE	10-1-59
APPROVED	
DRFT	R.D.
MODEL	AVS-321
DRAWING NO	1058-C
CHNG	C

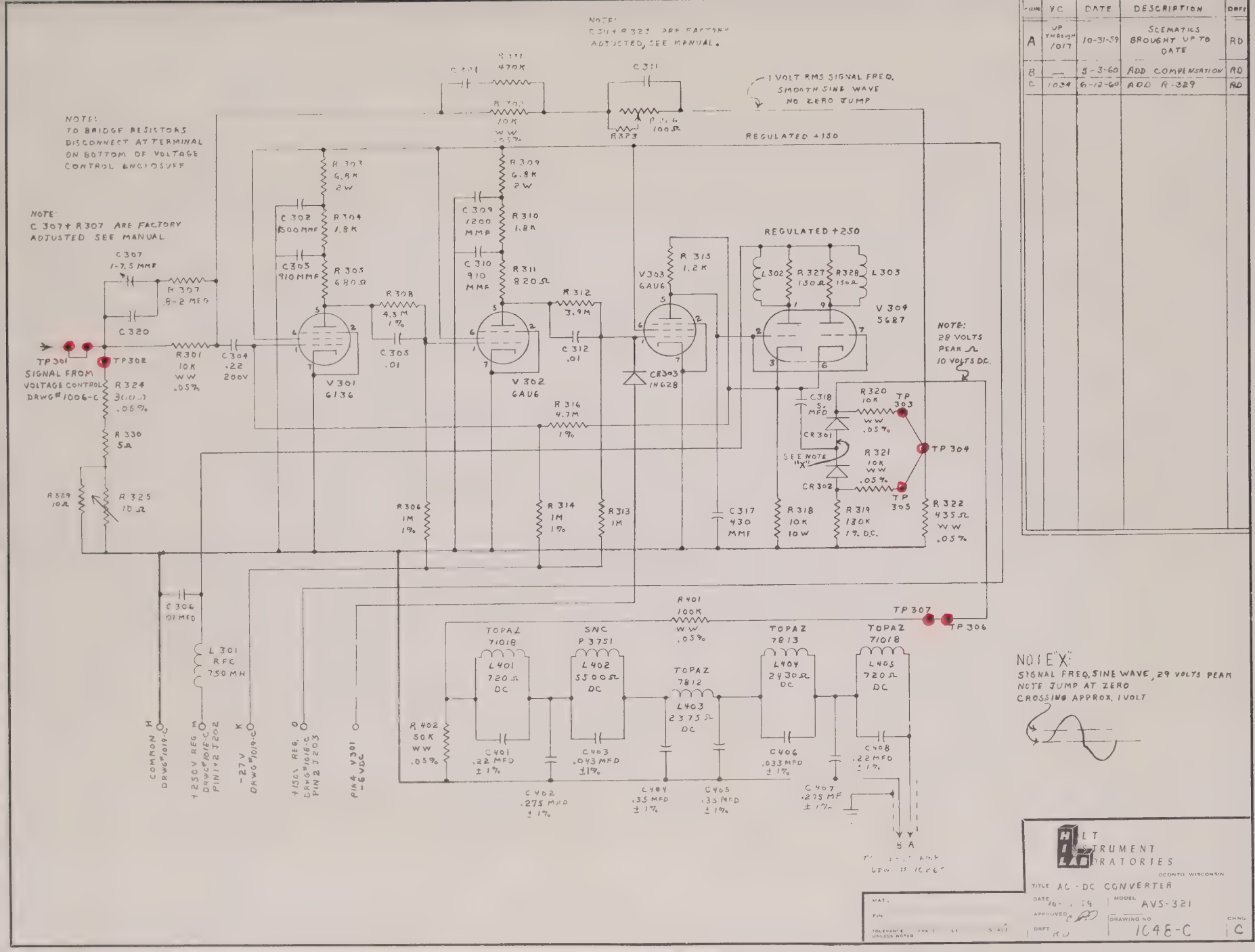


CHG	XC	DATE	DESCRIPTION	APP
B	1028	2-12-60	CHG TO 300 VOLT ATTENUATOR	RD
C	1031	4-5-60	ELIMINATE HIGH FREQ. COMPENSATION	

NOTE 1 FACTORY ADJ.

HILT INSTRUMENT LABORATORIES
OCONTO WISCONSIN

TITLE	VOLTAGE CONTROL		
MAT'L		DATE 2-24-60	MODEL AVS-321
FIN.		APPROVED	
TOLERANCE UNLESS NOTED: FRACT. DEC.	SCALE	DRFT RD	DRAWING NO 1006 CHNG C

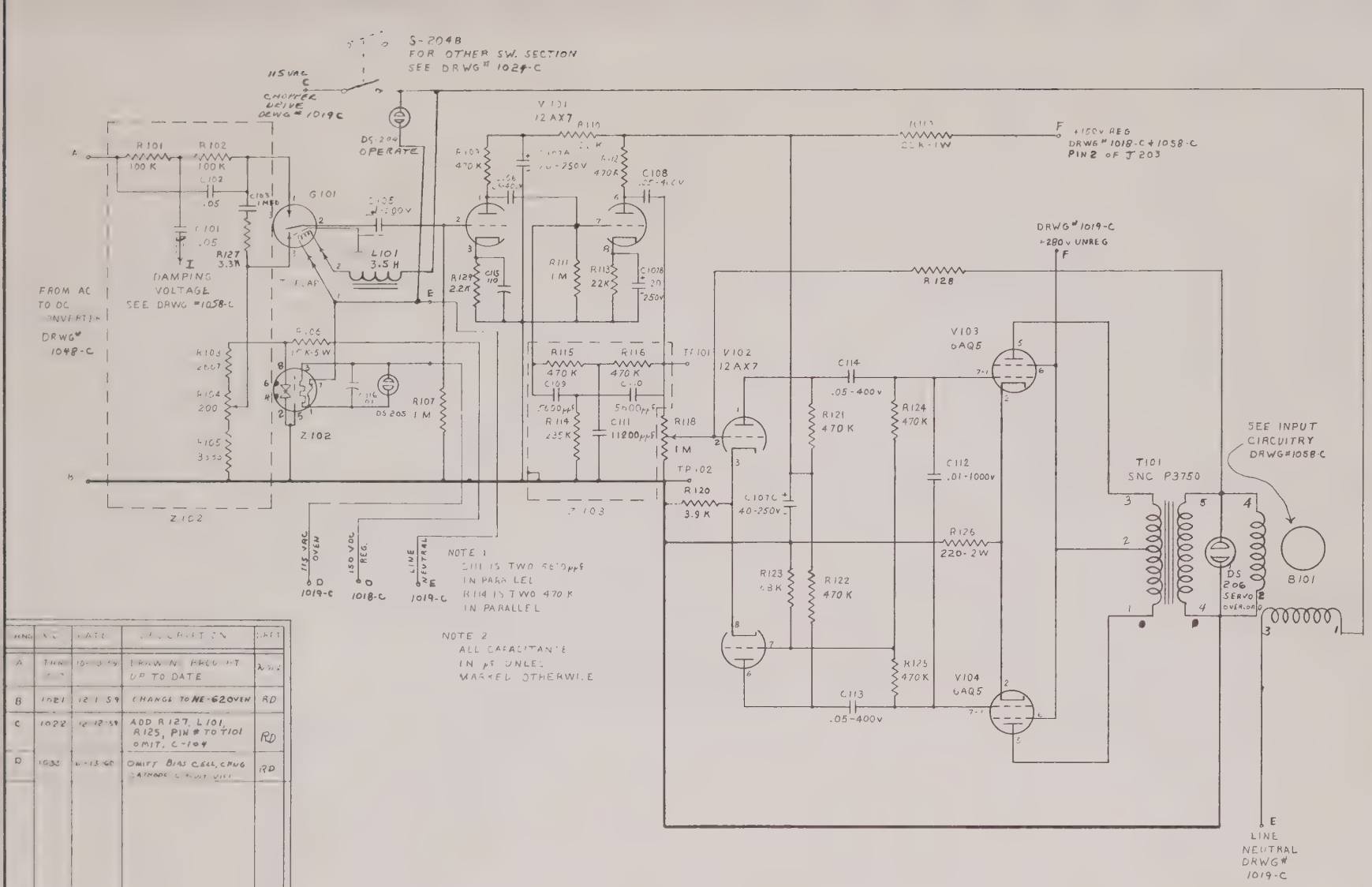


NOTE "X":
SIGNAL FREQ. SINE WAVE, 29 VOLTS PEAK
NOTE JUMP AT ZERO
CROSSING APPROX. 1 VOLT

LTR	BY	DATE	DESCRIPTION	DRFT
A	UP THROUGH 1017	10-31-59	SCEMATICS BROUGHT UP TO DATE	RD
B	—	5-3-60	ADD COMPENSATION	RD
C	1034	6-12-60	ADD R-329	RD

HILT INSTRUMENT LABORATORIES
OCONTO WISCONSIN

TITLE AC-DC CONVERTER
MODEL AVS-321
DRAWING NO 1048-C
CHNG C
DRFT RD
DATE 10-1-59
APPROVED
MAT.
FIN
TOLERANCE UNLESS NOTED



ENG	NO	DATE	DESCRIPTION	CHK
A	1019	10-20-59	DRAWN FROM IT UP TO DATE	RD
B	1021	12 1 59	CHANGE TO NE-62 OVEN	RD
C	1022	12-12-59	ADD R 127, L 101, R 125, PIN # TO T101 OMIT, C-104	RD
D	1035	6-13-60	OMIT BIAS CELL, CHNG CATHODE C TO V 101	RD

HI LAB INSTRUMENT LABORATORIES OCONTO WISCONSIN

TITLE SERVO AMPLIFIER

MAT'L

FIN

TOLERANCE UNLESS NOTED FRACT DEC

DATE 7-21-60

APPROVED

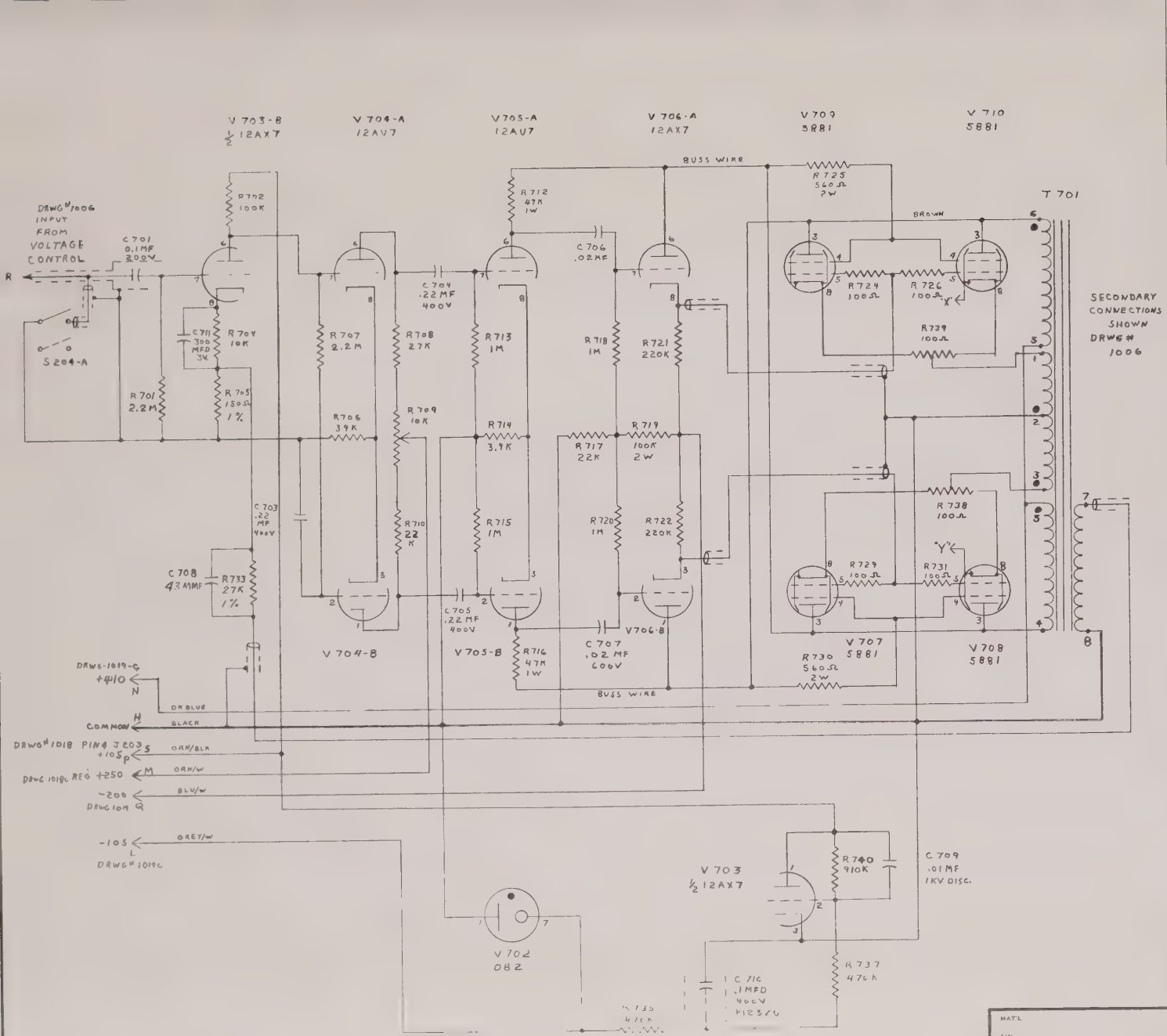
SCALE

DRFT

MODEL AVS 321

DRAWING

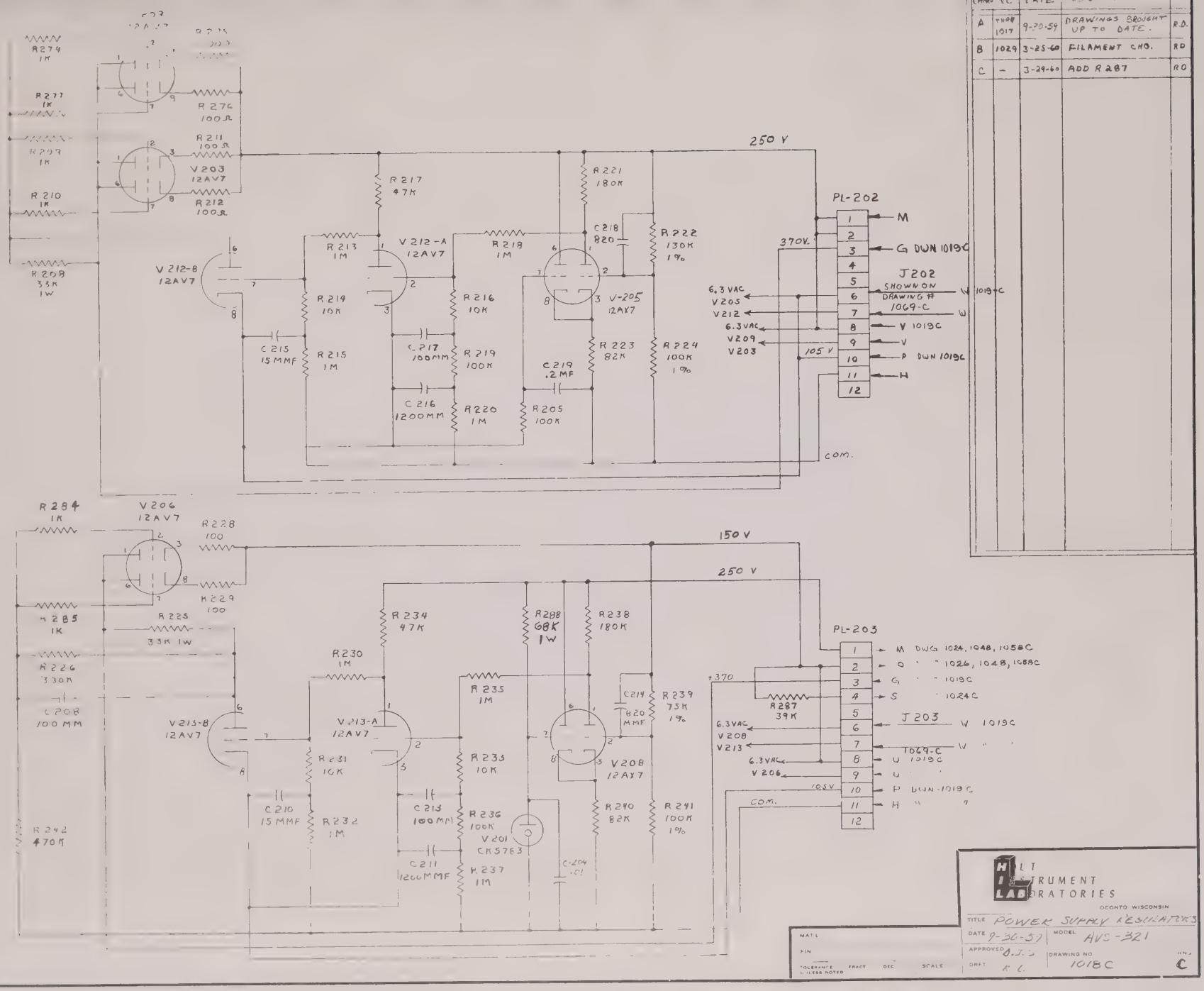
CHNG D



A	UP THROUGH 1017	10-31-59	SCHEMATICS BROUGHT UP TO DATE	RD
B	1027	1-27-60	R705, R733 & C 708 CHNGED	WJ

HI LAD INSTRUMENT LABORATORIES
OCONTO WISCONSIN

TITLE	POWER AMPLIFIER		
MAT'L	DATE 10-31-59	MODEL	AVS-321
FIN	APPROVED CWD	DRAWING NO	1024-C
TOLERANCE UNLESS NOTED FRACT DEC	SCALE	DRFT RD	CHNG B

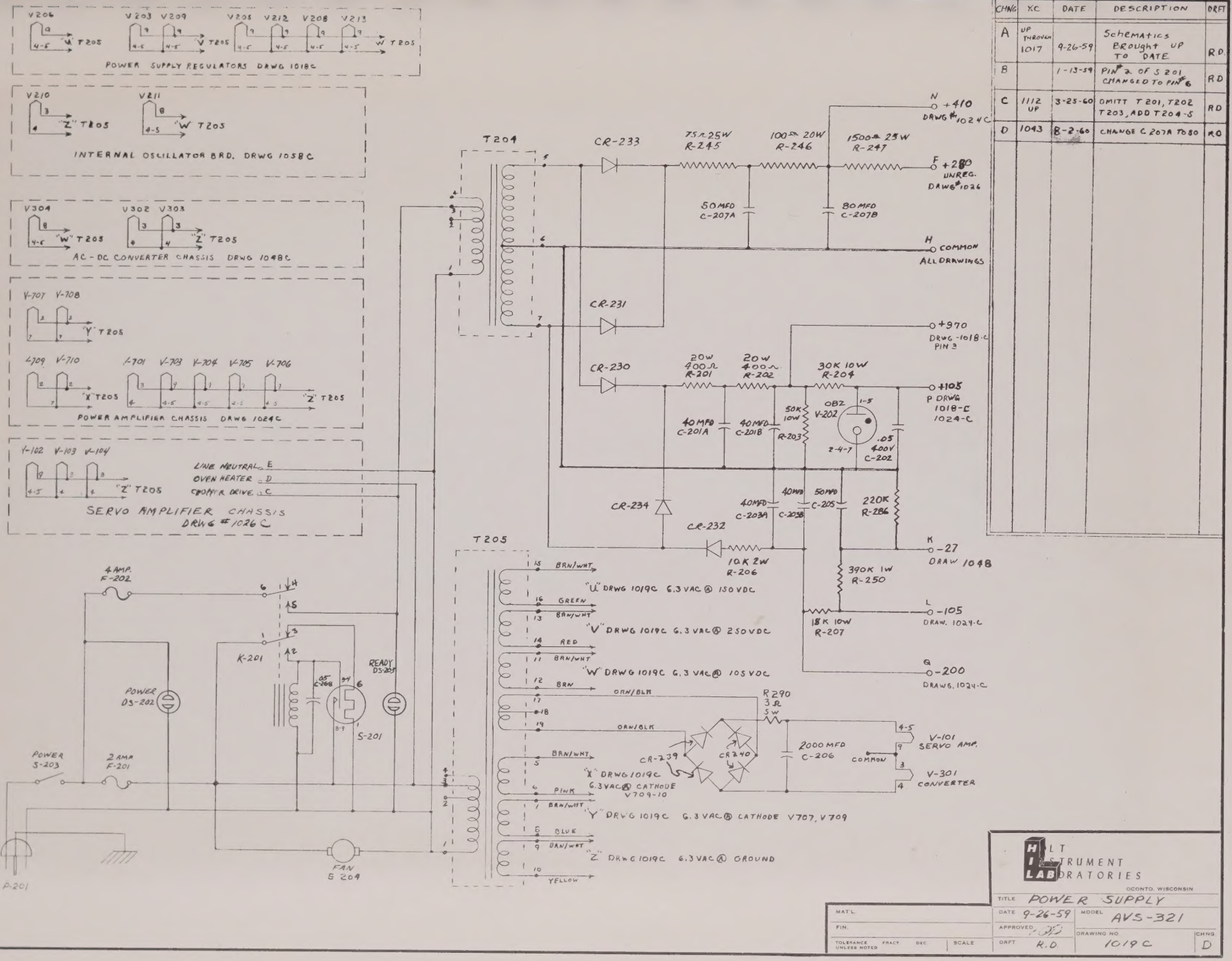


A	THRU 1017	9-30-59	DRAWINGS BROUGHT UP TO DATE.	R.D.
B	1029	3-25-60	FILAMENT CHG.	RD
C	–	3-29-60	ADD R 287	RD

HI LAB INSTRUMENT LABORATORIES
OCONTO WISCONSIN

TITLE POWER SUPPLY RESISTORS
DATE 9-30-57 MODEL AVS-321
APPROVED D.J.S. DRAWING NO 1018C
DRAFT K.L. DWG C

MAT'L
FIN
TOLERANCE UNLESS NOTED FRACT DEC SCALE



CHNG	XC.	DATE	DESCRIPTION	DRFT
A	UP THROUGH 1017	9-26-59	SCHEMATICS BROUGHT UP TO DATE	RD
B		1-13-59	PIN #2 OF S 201 CHANGED TO PIN #6	RD
C	1112 UP	3-25-60	OMITT T 201, T202 T203, ADD T 204-5	RD
D	1093	8-2-60	CHANGE C 207A TO 80	RD

HI LAB INSTRUMENT LABORATORIES
OCONTO, WISCONSIN

MAT'L.		TITLE	POWER SUPPLY
FIN.		DATE 9-26-59	MODEL AVS-321
TOLERANCE UNLESS NOTED: FRACT. DEC. SCALE		APPROVED	DRAWING NO. 1019C
		DRFT R.D	CHNG D

FACTORY TEST
DATA ENCLOSED
MODEL AVS-321
SERIAL 1193

KAROLTON KLASP® — 6½ x 9½
MADE BY
THE AMERICAN ENVELOPE CO.
WEST CARROLLTON, OHIO